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# Suspension System Principles

## Chapter Objectives

At the conclusion of this chapter you should be able to:

- Describe the functions and operational principles of modern suspension systems.
- Identify the types of front and rear suspensions.
- Identify the components and their functions of the front and rear suspension systems.
- Explain how changes in wheels and tires affect the suspension.
- Explain the basic operation of electronically controlled suspension systems.

### KEY TERMS

<b>air springs</b>	<b>Leaf spring</b>	<b>shock absorber</b>
<b>Coil spring</b>	<b>live axle</b>	<b>spring rate</b>
<b>dead axle</b>	<b>load-carrying ball joint</b>	<b>sprung weight</b>
<b>dependent</b>	<b>MacPherson strut</b>	<b>Stabilizer bar</b>
<b>frame</b>	<b>modified strut</b>	<b>Torsion bar</b>
<b>frequency</b>	<b>multilink</b>	<b>track bar</b>
<b>I-beam</b>	<b>Oversteer</b>	<b>understeer</b>
<b>independent</b>	<b>rebound</b>	<b>unibody</b>
<b>jounce</b>	<b>semi-independent</b>	<b>unsprung weight</b>

## Functions and Basic Principles

Suspension systems have evolved significantly since the earliest adaptations from horse-drawn buggies to self-powered automobiles, but the basic requirements remain the same. Just as in the horse and buggy days, today's suspension systems must provide for safe handling and maximum traction while being able to sustain passenger comfort. To accomplish these goals, modern suspension systems rely on various types of springs, shock absorbers, control arms, and other components. As a comparison, the front suspension from a Ford Model T and from a modern vehicle are shown in **Figure 6-1** and **Figure 6-2**.

All of the components of the suspension system must work together to provide the proper ride quality and handling characteristics expected by the driver and passengers. Each component is engineered to work as a part of the overall system. If one part of the system fails, it can lead to faster wear or damage to other components. Therefore, a complete understanding of each component and how it functions as part of the whole suspension system is critical.

### FUNCTIONS OF THE SUSPENSION SYSTEM

All suspension systems have the same basic functions to perform, regardless of the type of suspension system used on the vehicle.

- The tires must be able to rise and fall, relative to the body, to allow the springs and shocks to reduce bump and road shock.
- The suspension allows the springs and shocks to absorb the energy of a bump for a smooth ride while not allowing uncontrolled movement of the tires.
- The suspension must handle movements caused by vehicle acceleration, braking, and cornering.



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**FIGURE 6-1** For many years, suspensions were very basic, such as on this Model T.



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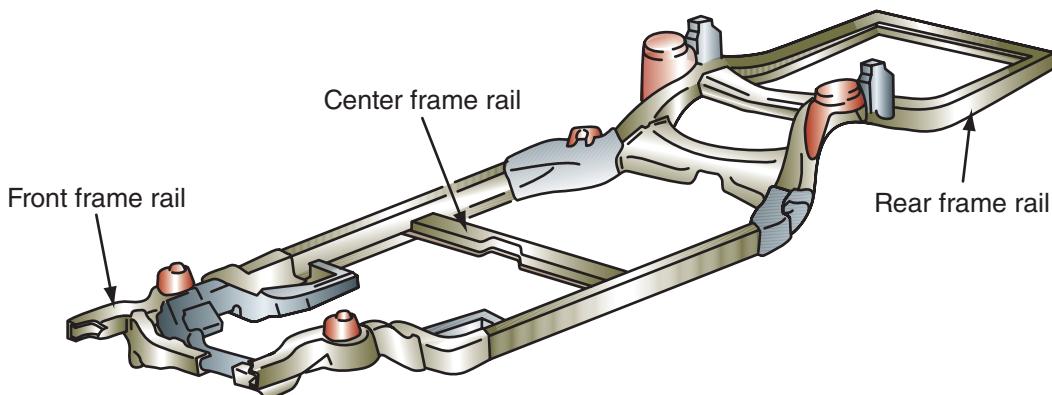
**FIGURE 6-2** A modern suspension system uses many aluminum parts and maximizes handling and ride quality.

- The springs must be able to safely carry the weight of the vehicle. **Figure 6-3** shows an example of a failed spring and its obvious effect on ride height. The failure of the spring not only affects the ride height for that corner of the vehicle, the spring's ability to carry weight is now gone. This results in a very rough ride and increases the loads and stresses placed on other components.
- It is important for the suspension to keep the alignment of the tire as correct as possible so that maximum contact is maintained between the tire and the road.



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**FIGURE 6-3** A weak spring has a very noticeable effect on ride height and will affect ride quality.



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**FIGURE 6-4** A ladder frame has side rails and crossmembers to build a strong foundation for the vehicle.

- The rear suspension must carry the weight of the rear of the vehicle and any additional loads in the trunk, cargo area, or bed.

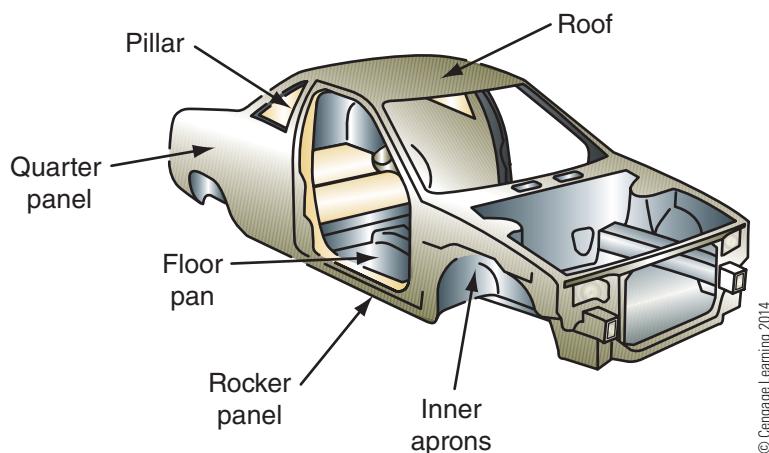
Regardless of type, the suspension carries the weight of the vehicle. Through the springs and other suspension components, the weight of the vehicle and its occupants is transferred to the wheels and tires. While this may sound simple, carrying around a two- or four-ton vehicle is not an easy task. Not only is the vehicle weight a load, but the additional forces of cornering, braking, accelerating, and negotiating every bump and dip in the road are applied to the suspension and tires. Engineers must balance weight carrying, ride control, comfort and handling when they are designing a vehicle.

## VEHICLE FRAMES

In use for decades, the body-over-frame design has the vehicle body as a separate component that, when assembled, is bolted to the frame. The **frame**, shown in **Figure 6-4**, is often ladder shaped, with two long frame rails that run the length of the vehicle and several

crossmembers attached to the frame rails. The crossmembers carry the engine, transmission, and front suspension and tie the frame rails together. The front suspension is bolted to the frame and front crossmember. The rear suspension bolts to the rear of the frame and rear axle. The combined weight of the body, frame, passengers, and any other loads push down on the springs, which in turn pass the weight through parts of the suspension and finally to the tires. Rubber bushings are placed between the frame and the body to help isolate noise, vibration, and harshness (NVH) from the suspension system. This body-over-frame design was used on the Ford Model T and continues to be used today on trucks and SUVs. Body-over-frame construction is strong but is also heavy and can allow unwanted flexing or twisting of the frame.

Most modern cars and small SUVs use a space frame or unitized body. This design does not have a separate frame. The body is constructed of many parts that are then assembled into a single unit, which is also the frame. This is called **unibody** construction and is shown in **Figure 6-5**. Once assembled, the outer body



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**FIGURE 6-5** Unibody frames provide the structure of the vehicle and are very rigid.

panels are attached to the unibody. The front and rear suspension systems are attached to the space frame with insulating rubber bushings, as in body-over-frame vehicles. This reduces the transmission of noise and vibration. The unibody frame reduces vehicle weight, increases strength and rigidity, and allows a wider variety of body designs.

With both types of vehicle construction, the majority of the weight of the vehicle is carried by the springs. The springs provide the support to hold the frame up and absorb the road shocks and movement of the vehicle while it is in motion. Different types of springs and suspension systems are used depending on the type of vehicle.

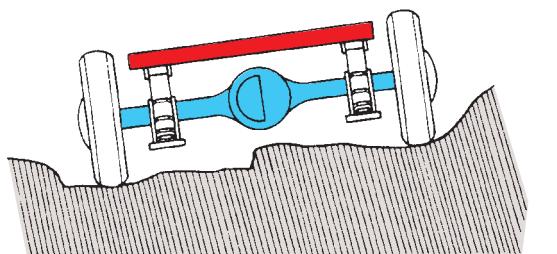
**Independent Suspensions.** To provide the best possible ride quality, many vehicles use fully **independent** front and rear suspension systems. This allows the vehicle to respond to varying road conditions much more effectively. Nearly all front suspensions found on modern cars and light trucks are independent. Even four-wheel drive (4WD) vehicles often have independent front suspensions to improve their ride and handling qualities. The lower image in **Figure 6-6** shows how each wheel is able to move

in an independent suspension while the upper image illustrates the movements of a dependent or rigid axle. In an independent suspension, each wheel can move independently, so a bump on one side of the vehicle does not affect the tires on the other side. This improves ride quality and maintains tire contact with the road for the remaining tires.

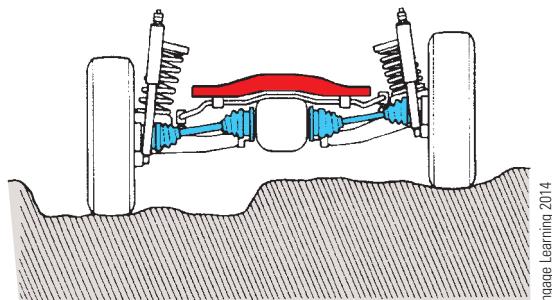
Many rear suspensions on rear-wheel drive (RWD) vehicles are independent systems. The differential is mounted solidly to the body or rear frame and short axles, similar to those found on the front of front-wheel drive (FWD) vehicles, are used to drive the rear wheels. This provides improved ride quality and handling. These suspension types are discussed later in this chapter. Many FWD cars have independent rear suspension systems as well. This improves ride quality and handling.

**Dependent Suspensions.** Still found on the rear of many vehicles and on the front of most heavy-duty vehicles, **dependent** suspensions sacrifice ride quality for strength. Since the movement of one wheel affects the opposite wheel, ride quality and handling suffer on these systems. A large, straight I-beam is often used on the front of heavy-duty vehicles, such as buses and semi trucks. An example of this is shown in **Figure 6-7**. This design is used for its strength and durability but does not provide the best ride quality.

The rear axle on many RWD cars, light trucks, and SUVs is a dependent **live axle**; an example is shown in **Figure 6-8**. Live axle means the rear axle is driving the rear wheels. Since a live rear axle is one large assembly housing the differential gears and axles, it is a dependent system. Live rear axles are mounted on leaf springs, coil springs, or air springs.



Rigid axle suspension



Independent suspension

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**FIGURE 6-6** Rigid and independent suspensions and their effect on wheel movement. Independent suspensions allow much improved ride quality and handling compared to dependent suspensions.



**FIGURE 6-7** Heavy I-beams are used on medium and heavy-duty trucks.

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**FIGURE 6-8** A live axle is used to drive the rear wheels and act as part of the rear suspension.

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A vehicle with a solid rear axle that does not drive the rear wheels has what is called a **dead axle** or a rigid or straight axle. An example of this type of rear suspension is shown in **Figure 6-9**. A dead axle supports the weight of the rear of the vehicle and can be fitted with coil, leaf, or air springs. A dead axle is a dependent form of suspension.

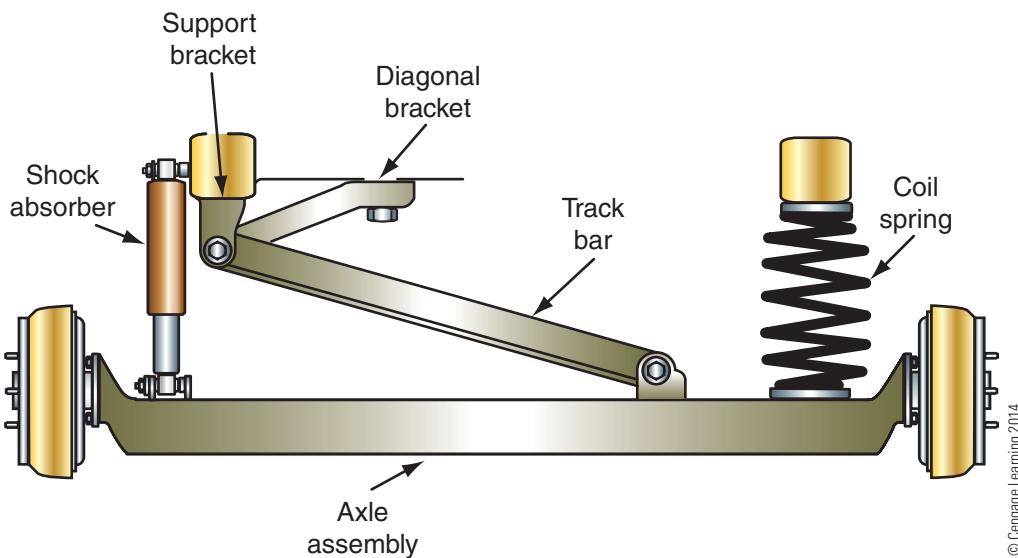
■ **Semi-Independent Suspensions.** Found on the rear of many FWD vehicles, this type of system uses a fixed rear axle that twists slightly under loads. This allows for **semi-independent** movement of the rear

wheels. This system typically uses coil springs or struts. The semi-independent system provides better ride and handling than a straight axle while not being as costly as a fully independent system.

■ **Front Suspensions.** The main purpose of the front suspension is to provide safe, comfortable handling while allowing wheel movement for the steering and enabling the driver to react to various road conditions. To accomplish this, several different front suspension styles are used in modern vehicles. The front suspensions on FWD vehicles also have to be able to handle the additional torque of driving the front wheels. Additionally, during braking, as much as 70 percent of the vehicle weight is transferred to the front, adding additional loads to the front suspension.

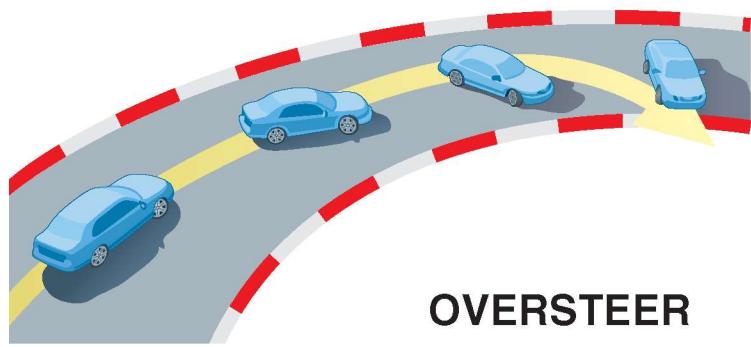
Vehicle type and intended use of the vehicle are the main considerations when engineers begin to design the suspension systems. Many cars have suspensions that look very similar, but actually have many differences. The exact size and placement of components have a large effect on individual vehicle driving characteristics.

■ **Rear Suspensions.** The rear suspension must be able to carry any additional loads placed in the rear of the vehicle while still maintaining the correct ride height. The rear suspensions on many FWD and RWD vehicles are similar in that a solid type of axle is used. Though strong, a solid axle does not provide the level of handling and ride quality that an independent rear suspension does. The rear suspension on RWD vehicles must be able to handle the torque of the driveline. This can be difficult since torque tries to twist the vehicle and rear suspension.



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**FIGURE 6-9** An example of a nondriving dependent rear suspension common on FWD vehicles.



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**FIGURE 6-10** Oversteer occurs when the back of the vehicle slides out and puts the vehicle into a spin.

## BASIC PRINCIPLES

The components of the suspension system, while important separately, must operate as a whole for the system to provide all of the requirements during normal driving conditions. As stated before, the suspension is responsible for carrying vehicle weight, absorbing road shocks, providing a smooth ride, and allowing good handling qualities.

While many drivers do not know the specifics of how these goals are met, they do feel how their vehicle rides and handles and can tell quickly when something is not quite right. For the technician, it is important to understand the underlying principles of suspension operation so that he or she can accurately diagnose a concern when one is present.

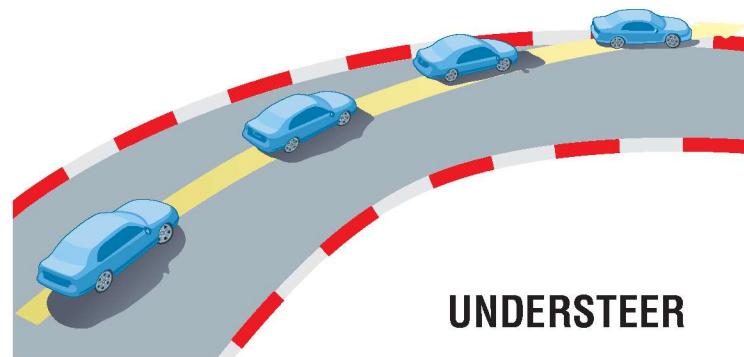
■ **Oversteer.** Oversteer is a term used to describe a driving condition where the rear tires reach their cornering limit before the front tires. This can allow the rear tires to break loose and cause the vehicle to spin. **Figure 6-10** illustrates the effects of oversteer. Oversteer can be used as an advantage in certain racing situations, but if you have ever experienced the back end of a car sliding on wet or slippery pavement, you know that oversteer can also be a very undesirable event! To correct

for oversteer, you should steer into the slide and reduce power until control returns. Applying the brakes can actually make oversteer worse since the weight transfer from the rear wheels can reduce rear tire traction.

■ **Understeer.** The opposite of oversteer is **understeer**. This condition occurs when the front of the vehicle cannot make a turn through the desired turn radius because the front tires have lost traction. **Figure 6-11** shows how a vehicle will continue in a somewhat straight line instead of making the intended turn. This causes the vehicle to overshoot the turn. If you have ever tried to make a turn in slippery or snowy conditions and the vehicle continued in a straight line instead of turning the corner, you have experienced understeer.

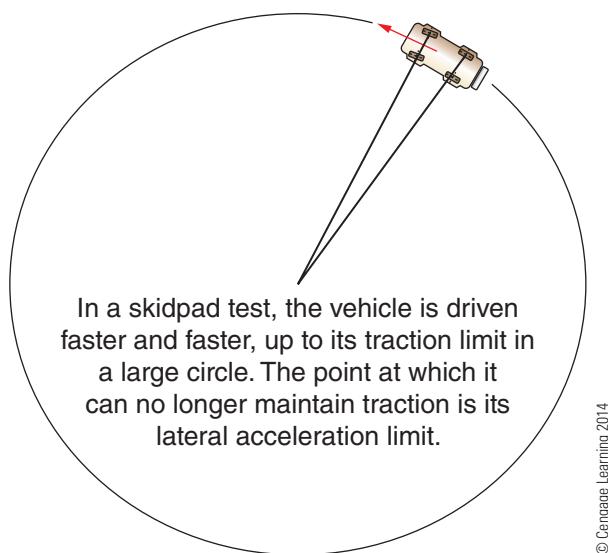
Understeer is measured by the difference between the angle the tires are pointing and the angle needed to make the turn. Most cars are designed to have understeer. This is because understeer can be reduced by reducing vehicle speed, which is safer for the average driver.

■ **Neutral Steering.** If a vehicle turns at the same rate that the steering wheel is turned, it is said to have neutral steering. This means that the vehicle does not exhibit a tendency to either over- or understeer.



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**FIGURE 6-11** Understeer occurs when the front wheels cannot provide enough traction to move the vehicle through the desired turn.



**FIGURE 6-12** Lateral acceleration tests a vehicle's ability to grip the road and corner.

■ **Lateral Acceleration.** Lateral acceleration is the measurement of the vehicle's ability to corner. What we feel during a corner is that a force pushes the vehicle and its occupants to the outside of a turn. In reality, as both the car and occupants turn, the people inside are still subject to Newton's First Law of Motion and continue to move in a straight line. The effect is that we feel pushed toward the outside of the corner. Centripetal force, meaning "toward the center," is the force that pulls an object toward the center of a circle as the object rotates. Imagine swinging a ball over your head and that the ball is attached to a string. The ball travels in a circle because the centripetal force is pulling the ball toward the center. Obviously, cars do not have strings pulling them in toward the center of a circle while turning but they do have tires. The tires are exerting the force toward the center. The lateral (sideways) force is perpendicular to the direction the car is traveling. This is where the term lateral acceleration comes from for vehicle test scores. The test is performed by driving the car on a large test-track circle at ever-increasing speeds. The faster the car can go around the circle, the greater the lateral acceleration. This means the better the vehicle will handle when cornering. **Figure 6-12** shows an illustration of how this test is performed. Low riding, wide wheelbase sports cars can achieve a much higher lateral acceleration than a vehicle that is higher off the ground, such as a minivan or SUV.

## Springs

The springs in the suspension have two important functions. Springs support the vehicle weight and absorb the bumps and movements that occur when driving. There are four types of springs used in suspension systems.

**Coil springs**—are a length of steel wound into a coil shape. Used on most front and many rear suspensions, coil springs, such as those shown in **Figure 6-13**, are large pieces of round steel formed into a coil. The spring absorbs energy as the coils are forced closer together. This is called compression. The stored energy is released when the coil extends back out. The energy continues to dissipate as the spring bounces. Eventually, the energy is exhausted and the spring stops bouncing. Coil springs are found in front and rear suspension systems, have a compact design, and do not need maintenance. When the spring becomes fatigued or weak, ride height will drop, and the spring will need to be replaced.

Coil springs are often sandwiched between the lower control arm and the vehicle frame. In this position, the weight of the vehicle is pushing down against the spring, which is supported by the lower control arm. This configuration allows movement of the suspension while the spring carries the weight and dampens out road shock. Coil springs often use rubber insulators between the spring and the frame to reduce noise.

The coil springs used in strut suspensions appear similar to those used in other applications, but are not interchangeable. Most strut coil springs are made of smaller diameter steel but are larger in total outside diameter than those in other applications. Strut coil springs are usually painted or coated with rust-resistant coverings.

Coil springs are categorized as either standard or variable-rate springs. A standard-rate spring has evenly spaced coils and requires a specific amount of force to compress the spring a given amount. Further compression requires an additional force, equal to the original force. A variable-rate spring has unequally spaced coils and requires an increasing amount of



**FIGURE 6-13** A selection of different coil springs. The first on the left is a front coil spring from a RWD truck with an SLA front suspension. The middle spring is a variable-rate rear coil spring and the right spring is a standard-rate rear spring.

force to achieve further compression. For example, a standard-rate spring may require 300 lbs. of force to compress one inch and an additional 300 lbs. to compress the second inch (600 lbs. equals two inches). A variable-rate spring requires the same 300 lbs. of force to compress one inch but requires 500 lbs. to compress the next inch (800 lbs. equals two inches).

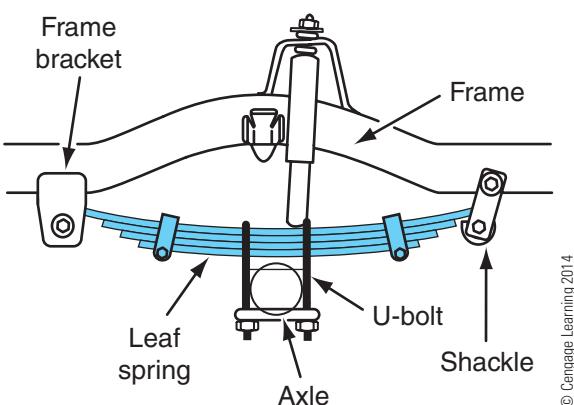
Coil springs used in passenger car rear suspensions are usually lighter duty than those found at the front. This is because the majority of the vehicle's weight is often toward the front. Coil springs on the rear of larger passenger cars, trucks, and SUVs are often variable-rate springs.

**Leaf springs**—are long semi-elliptical pieces of flattened steel and are used on the rear of many vehicles. Leaf springs are typically mounted as shown in **Figure 6-14**. Leaf springs have been in use since the horse-and-buggy days. A leaf spring is a long, flat piece of spring steel, shaped into a semicircle. The spring is attached to the frame through a shackle or bracket 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. Increasing the number of leaves increases load carrying capacity but makes the ride stiffer. Some suspensions use transverse leaf springs that are mounted perpendicular to the frame. In a transverse arrangement, one leaf spring supports both sides of the suspension. This style was used for many years on the Corvette and on some FWD vehicles with independent rear suspensions.

## Safety Warning



Coil springs contain stored energy. Improper service of the suspension or coil springs can release the spring, causing serious injury.



**FIGURE 6-14** Leaf springs are used in rear suspensions and can be placed either above or below the axle.

**Air springs**—are thick, tough bags filled with air that act as springs. Air springs are used on some larger sedans and most large commercial semi trucks and trailers. Air springs are typically located in the rear, though some manufacturers use air springs at both the front and the rear, as shown in **Figure 6-15**. Air springs, like torsion bars, are adjustable. On many vehicles, the on-board computer system uses a ride height sensor to determine suspension load. As additional weight is added to the trunk, the suspension will drop. When the computer senses this drop, it can turn on an on-board air compressor to supply more air to the air springs. The increased pressure in the springs will restore the

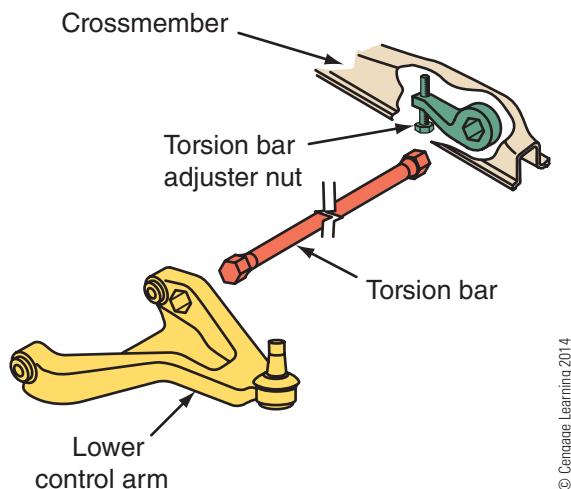
## Service Warning



Vehicles with air springs often require special lifting and jacking procedures. Do not attempt to raise a vehicle with air springs until you have read and followed all applicable warnings and procedures.



**FIGURE 6-15** Air springs are used in some rear suspensions and are very common on heavy-duty trucks.



**FIGURE 6-16** Torsion bars are long, straight, steel bars that twist to absorb energy.

ride height to the desired position. Some systems may use the adjustment of air pressure to the air springs to control ride height based on the vehicle's speed or driver input.

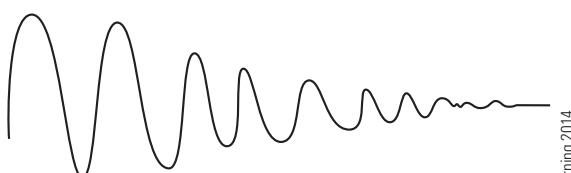
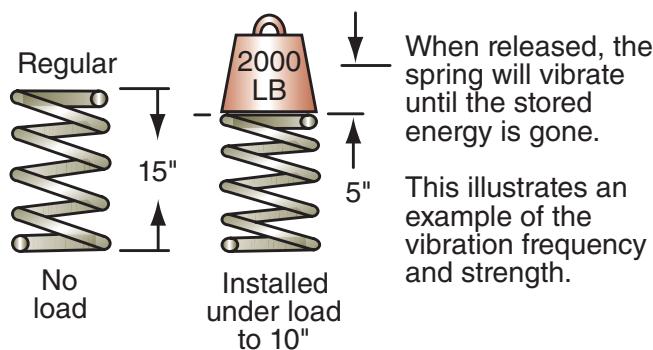
**Torsion bars**—are coil springs that are not coiled. Torsion bars are lengths of round steel bar fastened to a control arm on one end and the frame on the other end. Movement of the control arm causes the torsion bar to twist. The absorption of the twist is similar to compression of a coil spring. As the torsion bar untwists, the control arm returns to its normal position. Torsion bars are used in many 4WD vehicles where a front drive axle occupies the space where the coil spring normally sits. The torsion bar shown in **Figure 6-16** is mounted to the lower control arm and the transmission crossmember. Torsion bars can be mounted in either the upper or lower control arms. The control arm acts as a lever against the torsion bar, twisting the bar. The bar twists since it is rigidly mounted in a crossmember. As it releases energy and untwists, the torsion bar returns to its original shape, forcing the control arm back into position.

An advantage of torsion bars is that they are adjustable. At the rear torsion bar mount is an adjustment mechanism. If a torsion bar-equipped vehicle is sagging, the torsion bar may be able to be adjusted to bring the vehicle back into specification. When a torsion bar is replaced, it must be tightened to provide the necessary lift to support the vehicle.

## SPRING RATINGS

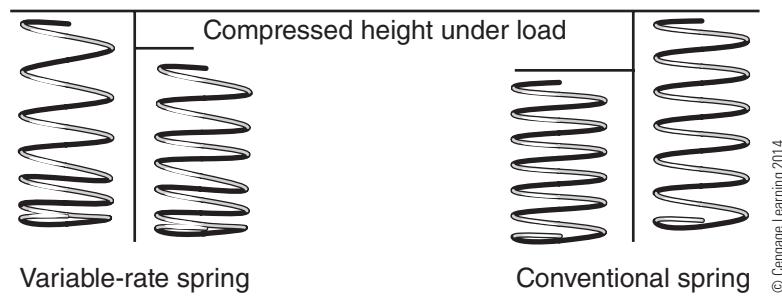
Automotive springs are rated for their frequency and their load rate. Springs, when either compressed or extended are under tension. When the tension is released, the springs will attempt to return to their original condition. When the springs are compressed or twisted, they store energy. Upward movement of the wheel that compresses the spring is called **jounce**. The stored energy is released when the spring rebounds. This downward movement of the tire, as the spring extends out, is called **rebound**. As you probably know, a compressed spring will rebound many times before all of the energy is dissipated. The number of times a spring oscillates or bounces before returning to its rest point is called the spring **frequency**. An example illustrating this is shown in **Figure 6-17**. The size of the spring and the spring material contribute to the spring frequency. Ideally, a spring should dampen out its oscillations quickly enough to provide a smooth ride but not so fast that it causes a harsh, jarring ride. If left to bounce or oscillate on its own, the spring will cause the vehicle to bounce excessively, probably to the discomfort of the passengers.

The amount of force it takes to compress or twist a spring a certain amount is called **spring rate**. Springs can have either linear or variable rates. **Figure 6-18** illustrates the differences in spring rate. When a vehicle is designed, the engineers will factor spring size, rate, and frequency based on the intended vehicle use, tire size and type, suspension style, and many other factors. The goal is to have the best compromise between component weight, vehicle cost, and the ride and handling qualities desired for the vehicle.



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**FIGURE 6-17** Springs dissipate their load at different rates depending on the size of the spring.



**FIGURE 6-18** Standard-rate springs will compress at a linear rate under load. Variable-rate springs stiffen as the load increases.

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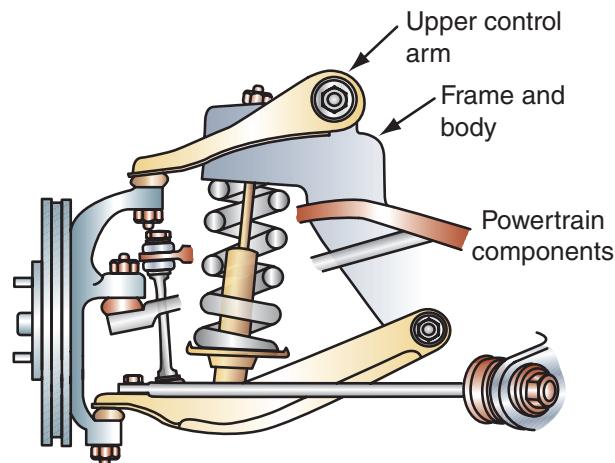
## SPRUNG AND UNSPRUNG WEIGHT

Weight carried by the springs is called **sprung weight**. Weight not carried by the springs is called **unsprung weight**. The less unsprung weight a vehicle has, the better the handling and ride will be. Some examples of unsprung weight are the wheels and tires, brake components, control arms, steering knuckles, and rear axles. **Figure 6-19** shows examples of unsprung weight. Sprung weight includes the vehicle body, engine and transmission, the passengers, and in general, items above the axles. Examples are shown in **Figure 6-20**. The amount of sprung weight should be high and unsprung weight should be low.

## SHOCK ABSORBERS

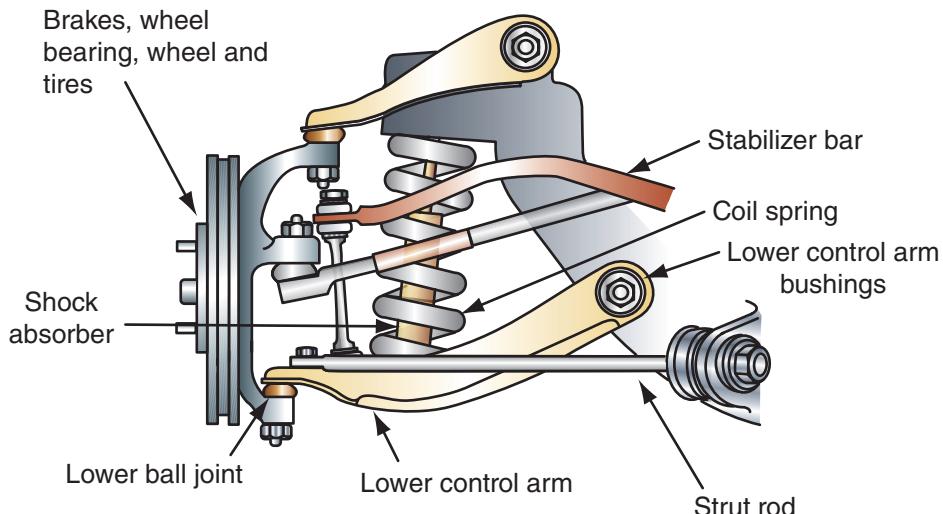
Shock absorbers are actually dampers, meaning that they reduce or make something less intense. The springs do the shock absorbing while the shocks dampen the spring oscillations. Without the shocks, our vehicles would continue to bounce for a long time after every bump, dip, and change in body movement.

The most common type of shock is the direct double-acting hydraulic **shock absorber**. This means that the shocks are used to directly act on motion; double acting means that they work in both compression and extension



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**FIGURE 6-20** Sprung weight is the weight carried by the springs.



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**FIGURE 6-19** Unsprung weight is generally components below the axles. The less unsprung weight, the better the vehicle will ride and handle.



**FIGURE 6-21** Shocks are mounted close to the springs. Exactly how and where varies extensively from vehicle to vehicle.

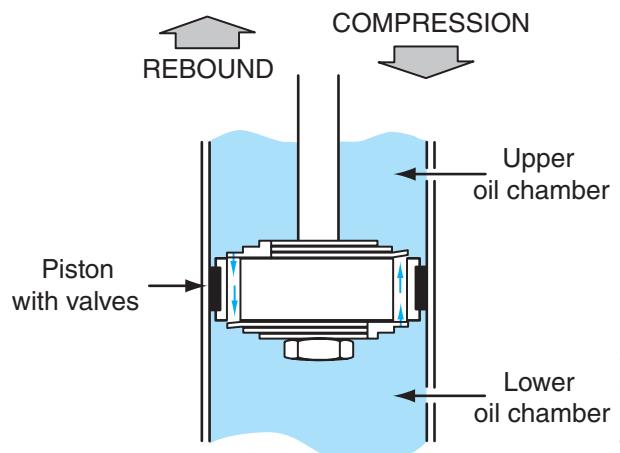
modes, and hydraulic means that a fluid is used to perform work. Compression is upward wheel travel, also called jounce. Extension is downward wheel motion and is also called rebound.

Shocks are typically mounted near the springs, with the lower end of the shock mounted on a lower control arm or axle, as shown in **Figure 6-21**. The top of the shock, which is connected to the shock piston, is mounted to the vehicle body. Inside the shock are two chambers, each partially filled with oil, as shown in **Figure 6-22**. The shock piston moves up and down in the main chamber. This movement displaces the oil into a second chamber. A set of one-way valves control the flow of oil from the chambers. Moving the oil is difficult. This is where the shock's resistance to movement comes from. **Figure 6-23** shows the movement of oil through the valves and chambers. By allowing more oil to flow, a shock will dampen less and provide a smoother ride. By restricting oil flow, the shock will be more resistant to movement and provide a stiffer ride.

A shock may have an equal amount of resistance during both compression and extension, or it may have more resistance during extension. This is because the spring naturally resists compression, and the shock does not need to add much resistance to that of the spring. But since the spring will easily extend out, the shock's



**FIGURE 6-22** The shock contains the piston, valves, and oil.



**FIGURE 6-23** The valves control the flow of oil through the shock.

greater resistance on extension can help better control spring action.

## CONTROL ARMS

Control arms are used to control wheel movement. Used on both front and rear suspensions, they are commonly referred to by their position, such as the upper and lower control arms. Common control arm configurations are shown in **Figure 6-24** through **Figure 6-26**. Control arms are also called A-arms or wishbones due to their similarity to being A- or wishbone shaped.



**FIGURE 6-24** Upper arms can be solid like this example or wishbone shaped to save weight.



**FIGURE 6-25** Lower control arms connect the steering knuckle to the frame and come in a wide variety of sizes and designs, like upper control arms.



**FIGURE 6-26** Control arms can also be simple straight arms as on the rear of this car.

A-arms typically have two connections to the frame and a ball joint for connecting to the steering knuckle. The control arm mounts to the frame with bushings. These bushings allow for up and down movement of the arm while controlling back and forth motion.

The bushings are generally rubber and steel and are pressed into the control arms. In addition to acting as pivots for the control arms, the bushings act as dampers, twisting and untwisting to return the control arm to its original position.

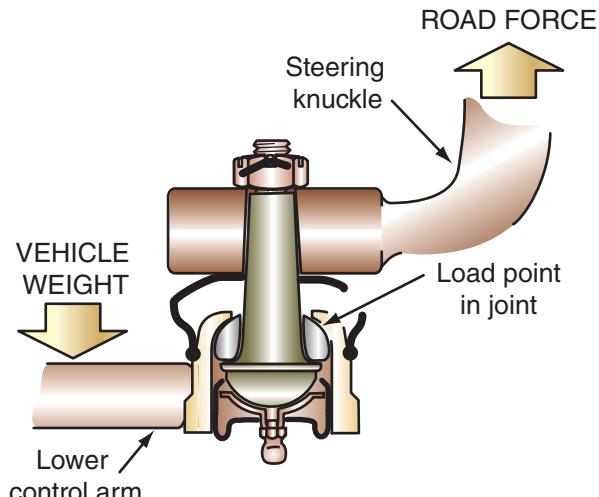
Also connected to lower control arms are the stabilizer bar links. The stabilizer bar links join the lower control arms to the stabilizer bar. These links can be a set of bushings and washers or a solid link with ball-and-socket joints.

■ **Ball Joints.** Ball joints allow the steering knuckle to pivot for steering while providing a tight connection to the control arms and preventing any unwanted up and down or sideways movement. Ball joints use a ball-and-socket joint to allow a wide range of motion, similar to a shoulder or hip joint. An illustration of a ball joint is shown in **Figure 6-27**.

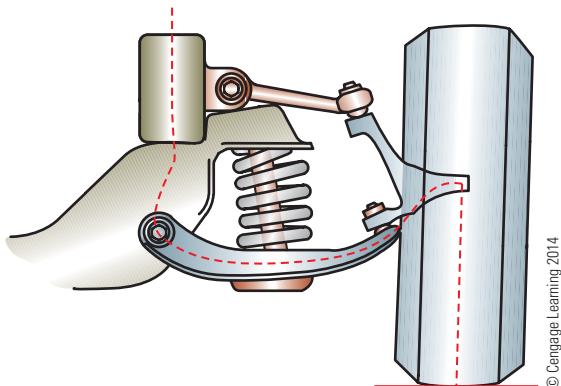
Ball joints can be one of two types, load carrying or nonload carrying. **Load-carrying ball joints** support the weight carried by the springs. Because of this, these joints tend to wear faster and need replacement more often than nonload-carrying joints. Nonload-carrying joints provide a steering pivot and component connection with a wide range of movement just like load carrying joints, but without the sprung weight applied to them. **Figure 6-28** illustrates how weight is carried by a ball joint.

Ball joints are mounted to the control arms in a variety of ways. The most common ways are a press fit, bolt in, and rivets. Some older vehicles had threads on the ball joint itself, which was then threaded into the control arm. Joints that are riveted at the factory are replaced with joints that bolt into the control arm.

Some heavy-duty and older vehicles use king pins instead of ball joints. A king pin connects the steering



**FIGURE 6-27** Ball joints allow for radial (turning) motion for steering and connect control arms to steering knuckles.



**FIGURE 6-28** In this suspension, the sprung weight is carried through the spring to the lower control arm, through the lower ball joint and through the steering knuckle to the tire.

knuckle to the front axle. King pins and king pin bushings do not use a ball-and-socket joint; instead, the king pin is pressed into the bushings. The king pin rotates in the bushing to allow for steering movement.

■ **Steering Knuckles.** Steering knuckles support the wheel and tire, brakes, and sprung weight of the vehicle. A steering knuckle can be mounted in a variety of ways for both front and rear suspensions. **Figure 6-29** shows an example of a common steering knuckle configuration. The steering knuckle also has an attachment point for the outer tie rod end. A wheel bearing or set of bearings mount to the steering knuckle to provide the mounting of the wheel hub.

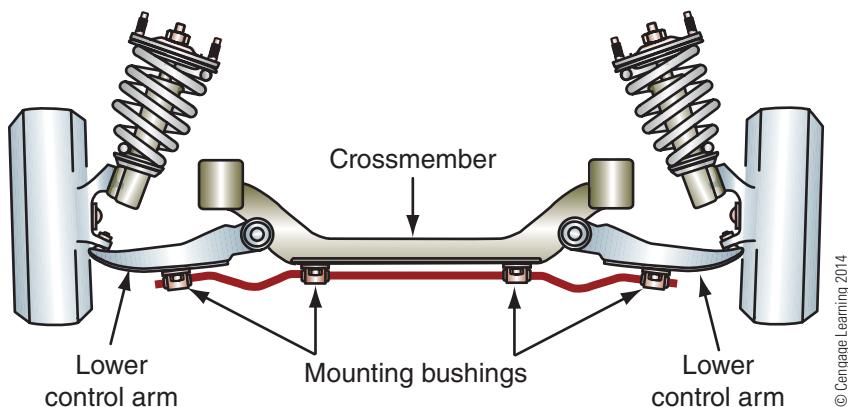
Steering knuckles are also sometimes called spindles. The spindle portion of the steering knuckle is where the wheel bearings and brake components are mounted. The spindle supports those components and allows the wheel to rotate on the wheel bearings.

■ **Stabilizer Bars.** Stabilizer bars, also called sway bars or anti-roll bars, reduce body roll. These steel bars attach to the lower control arms or axle assembly and the



**FIGURE 6-29** The steering knuckles on many cars and light trucks are made of aluminum, as shown in this picture of a Ford Explorer SUV.

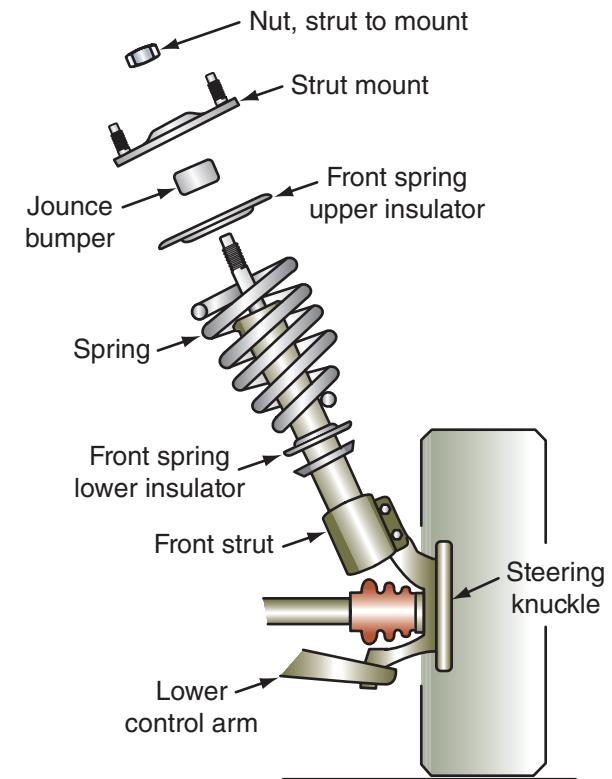
body or frame. When the vehicle body starts to lift while cornering, the bar tries to move with the body. Since the outer ends of the stabilizer bar are connected to the control arms or axle, and the control arms cannot move upward, it forces the stabilizer bar to pull the body back down, limiting body roll. An illustration of a stabilizer bar is shown in **Figure 6-30**. **Figure 6-31** shows how the stabilizer bar is connected to the control arm. Some vehicles have adjustable stabilizer bar links, while some modern sports cars use electronic anti-roll systems to reduce body movement. Regardless of the type, broken stabilizer bar links will cause excessive body roll while cornering.



**FIGURE 6-30** The stabilizer bar reduces body roll during turns and connects the lower control arms to the body with linkages and bushings.



**FIGURE 6-31** An example of a stabilizer bar link, connecting the bar to the control arm.



**FIGURE 6-32** An exploded view of a MacPherson strut assembly.

## Types of Suspension Systems

Even though there are many different suspension setups, most types can be categorized into one of these types: MacPherson strut, modified strut, multilink, short/long arm, I-beam, and solid axles. Regardless of the type, all suspensions try to accomplish the same goals of good ride quality and handling.

### MacPHERSON STRUTS

The popularity of small FWD vehicles has brought with it the dominate type of suspension system used today, the **MacPherson strut** suspension. These systems combine a coil spring, shock absorber, and bearing plate into a single unit. A typical strut is shown in **Figure 6-32**. This arrangement allows for greater engine compartment space and reduced weight compared to short/long arm suspensions. This is because the MacPherson strut suspension eliminates the upper control arm and upper ball joint. This reduces weight and moves the top of the suspension higher and toward the outside of the vehicle. Because the upper control arms are removed, there is space for the engine and transmission to be mounted transversely (sideways) in the engine compartment.

The strut connects to the car body through the upper strut mount or bearing plate, which also acts as a pivot and damper. The upper mount provides flexibility so the strut can change angle to follow the path of the

lower ball joint. The mount also dampens or reduces vibration and serves as the upper pivot for the steering axis. The components of a strut mount are illustrated in **Figure 6-33**.

The shock absorber's piston rod in a strut is larger than the standard shock piston rod to withstand sideways bending from loads placed on the tire while it is turning. **Figure 6-34** shows a comparison of a strut piston and a shock piston. The strut piston rod, on the left, is much larger in diameter than that of the shock, shown on the right.

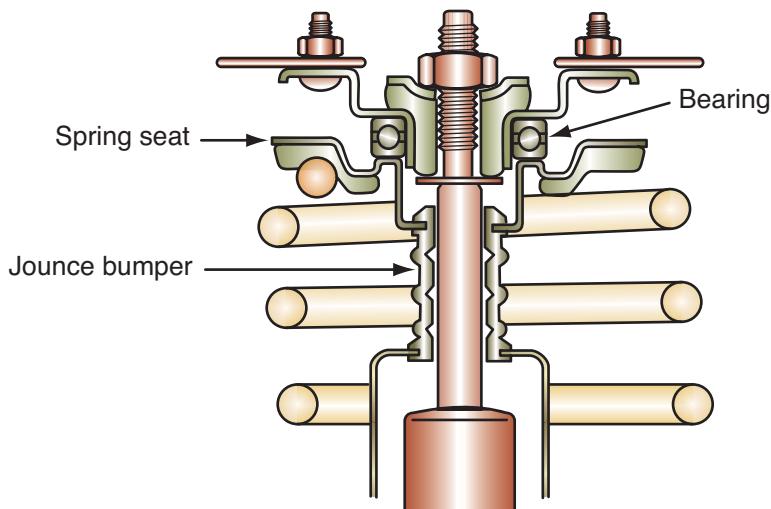
### MODIFIED STRUTS

Some vehicles use a strut-style shock absorber but relocate the spring. These are not true MacPherson struts. Called a **modified strut**, this system has the spring mounted separate from the strut. The strut performs the function of the shock absorber and is connected to an upper bearing

### Safety Warning



Since struts retain the spring under tension, special service procedures must be followed to prevent injury. Strut service is covered in detail in Chapter 7.



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**FIGURE 6-33** The upper strut mount/bearing plate allows the strut to turn as part of the steering system.



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**FIGURE 6-34** The piston in the strut on the left is much larger than the piston shown on the right. This is because the strut, in addition to being the shock, also is subject to sideways loads from cornering whereas the shock is not.

plate at the top and to the steering knuckle at the lower end. The coil spring is located between the frame and the lower control arm. This design has the weight and space saving advantages of the MacPherson strut suspension but can contain larger springs. Relocating the spring also



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**FIGURE 6-35** The modified strut suspension uses a strut connected to the upper body and steering knuckle but moves the coil spring off the strut assembly.

can allow for a wider distance between the wheel wells, increasing engine compartment room. A common modified strut configuration is shown in **Figure 6-35**.

### Safety Warning



Since the struts retain the spring under tension, special service procedures must be followed to prevent injury. Modified strut service is covered in detail in Chapter 7.



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**FIGURE 6-36** A multilink combines a nonturning strut and two or more control arms to control wheel movements. Taking the steering load off the strut allows for better handling.

## MULTILINK

Many vehicles use a multilink system. With a **multilink** suspension, the steering knuckle is taller than on a traditional strut or short/long arm suspension, often reaching the height of the top of the tire. The strut does not turn with the steering axis; rather it is mounted rigidly to the body at the upper strut mount. This is because the steering knuckle pivots on the upper and lower ball joints

for steering action. Multilink systems are designed to produce neutral steering on FWD vehicles, which tend to exhibit understeer with traditional MacPherson strut suspensions. This suspension is also commonly used on RWD cars, light trucks, and SUVs. **Figure 6-36** shows a common multilink arrangement.

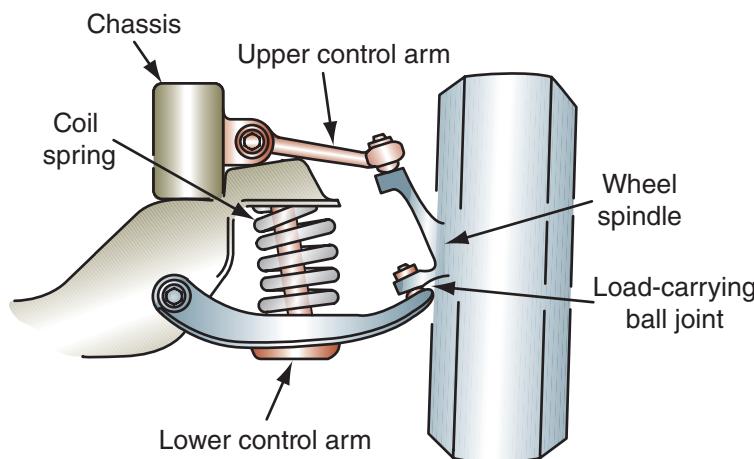
Multilink suspensions are also found on the rear of many vehicles, both FWD and RWD. Several control arms are used to reduce rear axle movements and provide better handling and ride qualities than a traditional rear strut system.

## SHORT/LONG ARM

Short/long arm suspensions, also called SLA suspensions, are typically used on RWD vehicles. This suspension consists of two unequal length control arms connected with a steering knuckle. The control arms are generally triangular and are often called wishbones or A-arms. A steering knuckle, control arm bushings and ball joints comprise the rest of the suspension. **Figure 6-37** shows an illustration of a typical system. Control arm design is matched with the spring for tire control and ride characteristics. The control arms are mounted to the frame with control arm bushings.

Some suspensions use a lower control arm with a single frame mounting point. In this case, a strut rod will also be used as an additional mount and stabilizer for the control arm as shown in **Figure 6-38**.

SLA systems use two ball joints, one of which carries the sprung weight of the vehicle. The other ball joint provides a friction and pivot point and does not carry weight. The load-carrying joint is located in the control arm in which the spring sits. The other ball joint is called the friction or following ball joint. **Figure 6-39** shows how the weight is carried by the load-carrying ball joint in an SLA suspension. SLA suspensions are



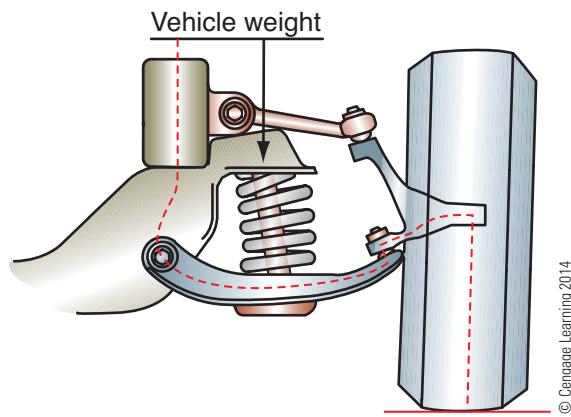
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**FIGURE 6-37** The SLA suspension uses two unequal-length control arms to control tire movements.



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**FIGURE 6-38** A strut rod is used when the lower control arm has only one mounting location. The strut rod forms part of the control arm and prevents forward and backward movement of the tire.



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**FIGURE 6-39** The sprung weight is carried from the spring to the lower control arm to the lower ball joint. The load then passes through the ball joint to the steering knuckle to the bearings, wheel, and tire.

not as common as they once were due to the popularity of FWD vehicles. These suspensions tend to intrude into the engine compartment, causing space problems with FWD drivetrains.

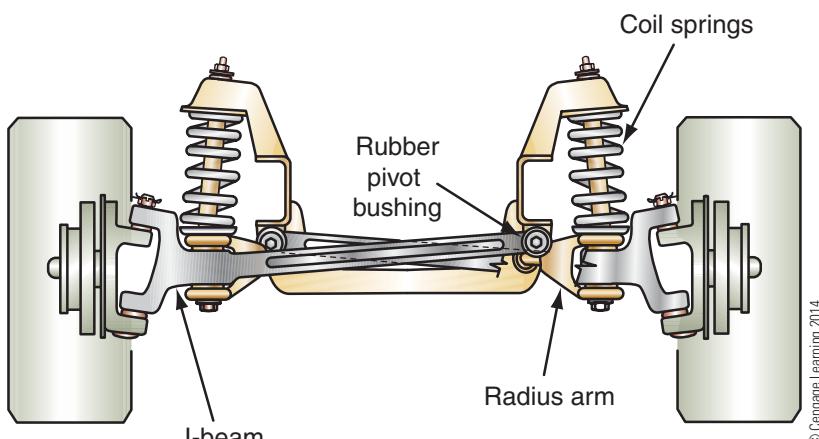
### I-BEAM

This suspension system was used on Ford trucks and vans for many years. Twin I-beams are strong and simple like solid axles but provide independent movement of the front suspension. An illustration of this system is shown in **Figure 6-40**. I-beams are mounted to the crossmember with a bushing and house the ball joints at the outside of the beam. I-beams also use a radius arm to control I-beam movement, as shown in **Figure 6-41**. I-beams are similar to very long control arms. They move on a pivot and allow for vertical wheel movement while the radius arm stops forward and backward movement of the suspension.

### 4WD SUSPENSIONS

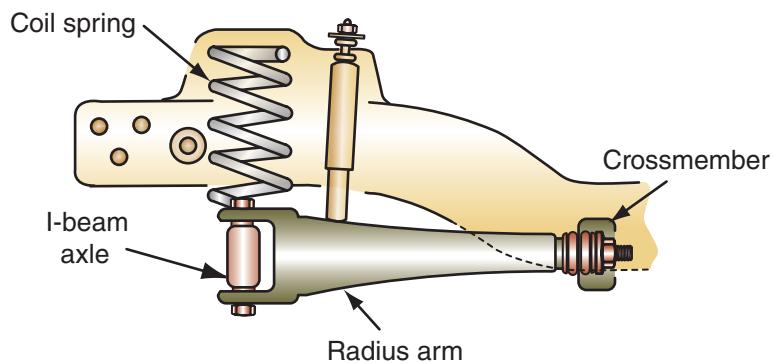
For many years, the front suspensions on 4WD vehicles were nearly identical to the rear suspensions. A large live axle supported with either leaf or coil springs for support was standard for most 4WD trucks, an example of which is shown in **Figure 6-42**. While strong, these systems did not have outstanding ride quality. To improve the ride and handling of 4WD trucks, manufacturers began to redesign the front suspensions to allow for independent wheel movement. One novel approach to this was Ford's Twin-Traction Beam or TTB. This system uses a live front axle that contains U-jointed axle shafts that allow for independent wheel movement for improved ride and handling while still retaining the durability and strength of traditional 4WD.

Manufacturers of 4WD vehicles today often mount the front differential directly to the chassis. Short FWD drive shafts then connect the differential to the wheels.



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**FIGURE 6-40** An example of the Twin I-Beam suspension used on Ford trucks and vans for many years.



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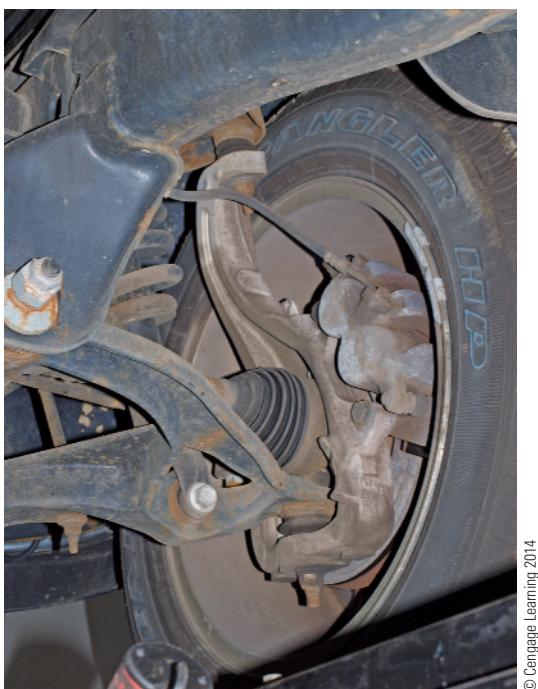
**FIGURE 6-41** The radius arm controls forward and backward movement of the tire on the Twin I-Beam suspension.



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**FIGURE 6-42** Live front driving axles are common only on the heavy-duty versions of 4WD trucks.

An example of this arrangement is shown in **Figure 6-43**. This allows fully independent suspension movement. Full live front axles can still be found on heavy-duty light trucks, but the majority of trucks now have independent front suspensions whether they are 2WD or 4WD.



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**FIGURE 6-43** Most 4WD trucks now use independent front suspension systems to improve ride quality.

## Tires, Wheels, and Bearings as Part of the Suspension

Tires and wheels are often thought of as independent components, not necessarily as part of the steering and suspension system. In reality, the tires have a large impact on the overall handling characteristics of a vehicle.

### How the Tires, Wheels, and Bearings Affect the Suspension

Since the tire is the only contact point between the car and the road, it plays an important part in ride quality and handling ability. Few components can affect both ride and handling as significantly as the tires. Tires are made of many different components and materials, as discussed in Chapter 5. These materials determine how stiff the tire will be, how much it will flex under loads, how much road shock will be transmitted to the rest of the suspension, and how well it will grip the road. These are important considerations with replacing the tires on a vehicle. Different tread designs behave differently under normal operating conditions. A vehicle with two or more different types of tires installed can experience handling, noise, and pulling concerns due to the dissimilar tread patterns.

Tire pressure also plays a role in ride quality and handling. Every modern vehicle has a recommended tire inflation pressure, which is found on a tire information decal, typically located on a doorjamb or the glove

box. Overinflating the tires can increase ride harshness and cause the center of the tread to wear more rapidly. Severe overinflation will bulge out the center of the tire and can be dangerous due to increased pressure and temperatures during driving. Underinflation of tires can also cause a rough ride, as well as increased rolling resistance and rapid wear and possibly wheel damage. An underinflated tire will have less cushioning ability than a properly inflated tire. Striking bumps and potholes can cause the tire to flex enough that the rim is damaged. Underinflation also places more load on the tire sidewall. This can lead to severe tire damage and tire failure in a very short time.

Before attempting to diagnose any suspension or steering concern, a very careful inspection of the tires should always take place. Always check the following:

- For correct tire size, type, and construction
- Tire inflation pressures
- Tire tread patterns and treadwear patterns

Wheels can affect the operation of the suspension system when the original wheels are replaced with different-sized wheels and tires. When the vehicle is designed, the suspension, steering, and alignment geometry are designed around specific wheel and tire dimensions. When wider or taller wheels are installed in place of the original wheels, clearance problems can arise, improper loading of wheel bearings can occur, and steering and suspension geometry can be altered with unexpected consequences. Any time a vehicle's alignment is being checked and aftermarket wheels are installed, do a thorough check of all alignment angles, not just the normal caster, camber, and toe. Incorrect wheels can affect scrub radius, which can cause severe pulling.

Wheel bearings typically only cause suspension problems when they are excessively worn and become loose. Faulty wheel bearings can cause noise and allow wheel movement, which can result in noise, pulling, and vibrations. Aftermarket wheel and tire installations can lead to damaged wheel bearings by changing wheel offset, and consequently, bearing loading.

### SPRUNG AND UNSPRUNG WEIGHT

As discussed earlier, sprung weight is weight carried by the springs. This includes the vehicle's frame and body, passengers, the powertrain, and most major components. Unsprung weight is weight not carried by the springs. This usually includes the wheels, tires, wheel bearings, brakes, the springs themselves, lower control arms, ball joints, and other similar components. The amount of sprung weight should be high, and the amount of unsprung weight should be low.

But how does this affect ride quality and handling? Every time a car hits a bump, the wheel, tire, brakes, and other unsprung parts have to move in response to the bump. This mass of parts has to accelerate upward, stop, and accelerate back down. The more mass that has to move, the slower it will react. By decreasing the unsprung weight, the suspension will be able to respond more rapidly to bumps and road conditions. This means the tire can regain contact with the road sooner after encountering a bump. In addition, since the shocks and springs still have to respond to movement by the unsprung weight, reducing this weight will allow the springs and shocks to better control the sprung weight of the vehicle, which is also responding to bumps, dips, potholes, and other road conditions.

## Front Suspension System Design and Components

While all front suspensions accomplish the same goals, different designs and arrangement are used on cars and light trucks to maximize particular qualities for specific vehicles. For example, a Chevrolet Corvette and a Chevrolet truck may both use short-long arm suspensions; however, the size, location, and mountings of the components will differ because of the two very different purposes of each vehicle.

### STRUT SUSPENSION SYSTEM DESIGN AND OPERATION

Strut suspensions have been around for many years and are used on nearly all FWD vehicles, as well as many RWD cars and even light trucks. The main advantages of strut suspensions are weight and space savings, simplicity, and low cost. The disadvantages include alignment change when moving vertically, reduced handling capabilities, and noise and harshness transmitted through the upper strut mount.

The most common type of strut is the MacPherson strut. Developed in the late 1940s and early 1950s, MacPherson struts did not become widely used until the adoption of unibody construction and the shift to producing FWD vehicles in the 1970s and 1980s.

The strut mounts to the body, often called the strut tower, which is in the engine compartment. The connection between the strut and the body contains a mounting plate or bearing plate. This plate contains either a bushing or bearing that allows for steering movement, as shown in **Figure 6-44**. The top of the shock piston is secured to the upper bearing plate with a large nut. When the steering wheel is turned, the upper section of the bearing plate stays in place while the lower section rotates on the bushing or bearing. The lower section of the strut assembly is bolted to

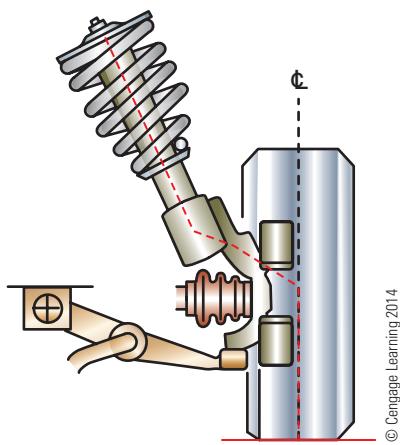


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**FIGURE 6-44** The upper strut mount and bearing allow the strut to pivot for steering.

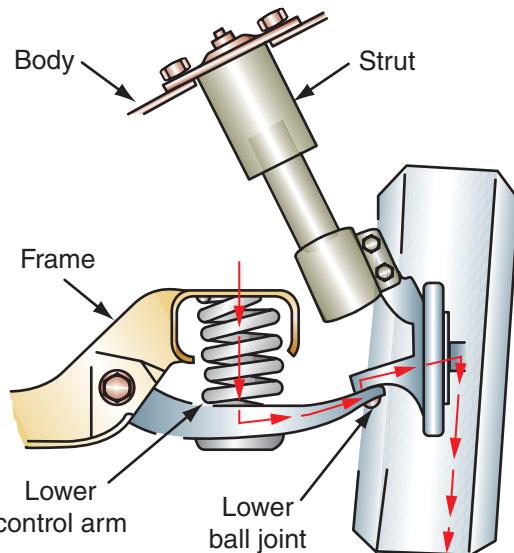
the steering knuckle. The steering knuckle is attached to the lower control arm with a ball joint. The strut replaces the upper control arm and ball joint, reducing the number of parts and vehicle weight. Since the strut mounts almost vertically to the body, the strut tower can be moved further out toward the wheels, which increases room in the engine compartment compared to SLA suspensions.

The sprung weight of the vehicle is applied to the spring via the upper strut tower and strut mount. This weight is then applied to the lower spring seat of the strut body, down the strut to the steering knuckle. The load is then transferred to the wheel and tire to the ground. **Figure 6-45** shows how the vehicle weight is carried by the strut suspension. The lower ball joint in this system is not a load-carrying joint. It acts as a friction joint only.



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**FIGURE 6-45** The MacPherson strut combines the shock, spring, and upper steering pivot into one unit. The load is carried through the spring and strut to the steering knuckle to the wheel and tire. The ball joint is not a load-carrying ball joint.



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**FIGURE 6-46** A modified strut relocated the coil spring but retains the strut and upper steering pivot from the MacPherson strut. However, the load is carried by the spring, lower control arm, and lower ball joint in the modified strut system.

## MODIFIED STRUT SUSPENSION SYSTEM DESIGN AND OPERATION

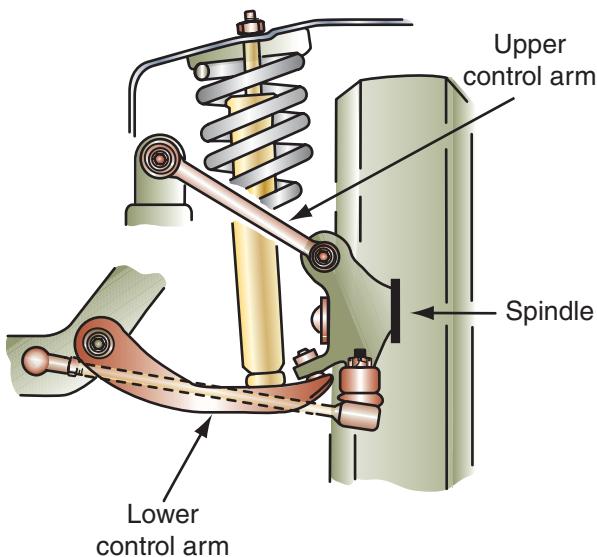
A modified strut suspension is similar to a MacPherson strut system, except that the coil spring is relocated, typically to where the coil spring normally sits in SLA suspensions. The coil spring is mounted between the lower control arm and the vehicle frame. Since the spring is now located on the lower control arm, the lower ball joint becomes a load-carrying ball joint. **Figure 6-46** shows a typical modified strut system and how it carries the weight of the vehicle.

The strut assembly now consists of the shock and the bearing plate mounted to the strut tower. As in MacPherson systems, the steering knuckle connects to the lower end of the strut body. Used extensively on GM Camaro and Firebird bodies as well as the Ford Mustang, this system offers the compactness of a strut suspension with improved ride and handling qualities.

## MULTILINK SUSPENSION SYSTEM DESIGN AND OPERATION

Multilink systems provide more neutral steering feel instead of the understeer normally associated with strut suspensions. As the name implies, the multilink system uses multiple components to achieve improved ride and handling qualities.

One obvious difference between the multilink and strut suspensions is that the multilink setup has both upper and lower control arms. In the multilink arrangement, the steering axis is between the upper and lower ball joints, just as in SLA systems. This removes the turning forces from the



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**FIGURE 6-47** A multilink arrangement uses a load-carrying ball joint because the sprung weight passes through the spring and strut to the lower control arm.



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**FIGURE 6-48** The SLA suspension is compact and provides good wheel control.

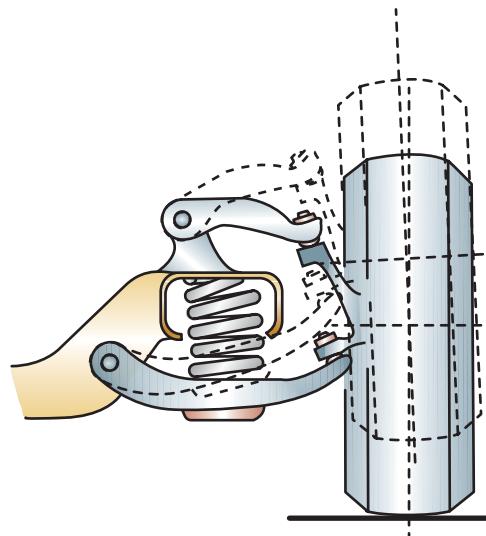
strut assembly, allowing for a more compact spring and shock. This also reduces the understeer associated with a strut suspension. Since the strut is not part of the steering system, there is no upper bushing or bearing in the upper strut mount. The load is carried by the lower ball joint since the strut is bolted to the lower control arm. **Figure 6-47** shows how the weight is carried by this suspension.

### SHORT ARM LONG ARM SUSPENSION DESIGN AND OPERATION

Short/long arm suspensions have been in service for many years. The advantages of this type of suspension are that it is compact, provides good handling and ride quality, and provides for substantial adjustment to fine-tune wheel alignment and ride characteristics.

Typically, a coil spring is sandwiched between the lower control arm and the frame, although many 4WD trucks and SUVs use torsion bars instead of coil springs. **Figure 6-48** shows a common SLA configuration. The majority of the weight of the vehicle is then pressing down on the coil spring where the spring meets the frame. The lower control arm, with the spring sitting on it, is then supporting the vehicle. The steering knuckle is connected to the upper and lower control arms by ball joints.

As the tire moves over a bump in the road, the lower control arm is forced up against spring tension. This is shown in **Figure 6-49**. The size and position of the A-arms help to keep the tire vertical as it moves up and down over the road. The spring absorbs the bump and limits how much the bump is transferred to the body. The shock absorber is typically mounted inside of the open center of the coil spring.



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**FIGURE 6-49** The size and shape of the control arms limit the amount the tire moves from vertical as it moves up and down.

### I-BEAM SUSPENSION DESIGN AND OPERATION

Until the mid-1960s, most trucks used a single I-beam front suspension. While very strong and durable, the single I-beam ride quality is less than comfortable. In 1965, Ford introduced the twin I-beam suspension. This allowed independent front wheel movement, which increased ride quality, vehicle control, and tire life.

The long I-beams are mounted off center on a pivot. This increases the amount of I-beam travel compared

to a single I-beam suspension, which allows for greater spring action and shock absorption. To limit any unwanted lateral movement, a radius arm is mounted to the outer end of the I-beam and through a bushing to the frame.

## 4WD SUSPENSION DESIGN AND OPERATION

Many 4WD trucks and SUVs use the SLA suspension, though typically with a torsion bar instead of coil springs, as shown in **Figure 6-50**. This is because the front drive axles pass through where the spring and shock are normally mounted in the SLA systems. Torsion bars are typically mounted to the rear of the lower control arm. This means the lower ball joint is the load-carrying joint. The rear of the torsion bar is mounted in the rear crossmember that supports the transmission. An adjustment mechanism is installed at the rear torsion bar mount. The adjustment is used to remove or apply tension to the torsion bar during suspension service. As the torsion bar weakens over time and the ride height begins to drop, this adjustment can be used to apply more tension to the bar and restore ride height.

Many heavy-duty 4WD trucks use a live front axle. This is because of the strength and durability of the axle. The live axle does not permit independent front wheel movement, so ride quality and handling suffer compared to a vehicle with an independent suspension. Typically, only the heavy-duty versions of a 4WD truck will have a live front axle because of this. Front live axles can be mounted with either coil or leaf springs, depending on the vehicle. The ends of the axle connect to the steering knuckle with ball joints.



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**FIGURE 6-50** Torsion bars are common on 4WD trucks and SUVs.

## Rear Suspension Systems

The rear suspension must meet the same requirements as the front, keeping the tires in contact with the ground, providing a smooth ride, and absorbing road shocks. However, the rear suspension does not have to accommodate steering except in a very few cases.

Even though it is not part of the steering, the rear suspension often has a much harder job keeping the tires in contact with the road due to the decreased amount of weight in the rear of most vehicles. In addition, providing adequate traction to the rear driving wheels can also be a challenge for the rear suspension due to unequal weight balance and overall suspension design.

## DEPENDENT REAR SUSPENSION SYSTEMS

Many FWD and RWD vehicles continue to use dependent rear suspension systems. This is due to low cost, ease of manufacture, low maintenance, and simple operation. Additionally, not every vehicle needs the improved ride and handling offered by independent rear suspension systems. Dependent rear suspensions are found on RWD vehicles like the Ford Mustang as well as most trucks, RWD vans, and larger SUVs. Most minivans and many FWD vehicles also have a dependent rear suspension system.

## DEAD AXLES

A dead axle is a common reference to a single rear nondriving axle, found on many FWD cars and minivans. **Figure 6-51** shows an example of this type of rear suspension. Essentially a hollow steel tube, the dead axle is mounted to the frame or body with control arms or



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**FIGURE 6-51** Dependent rear suspensions are used extensively on FWD cars and minivans.



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**FIGURE 6-52** An example of a rear live axle arrangement.

trailing arms. Each side has a spring and shock. Dead axles can be mounted to leaf springs, coil springs, or air springs. Strong and simple, dead axles provide adequate ride and handling qualities while being inexpensive and simple in operation.

### LIVE AXLES

Rear live axles can be either dependently or independently mounted. **Figure 6-52** shows the most common dependent rear live axle type of rear suspension. Most trucks and SUVs use a dependent rear live axle with either leaf or coil springs. Some larger luxury cars use air springs with the rear axle. RWD axles typically use some type of control arm to limit lateral movement and help control axle wind-up. Wind-up occurs when torque is applied to the rear axle, causing it to try to twist in response.

### INDEPENDENT REAR SUSPENSION SYSTEMS

Many sports cars and some trucks and SUVs use an independent rear live axle. **Figure 6-53** shows an example of an independent rear live axle suspension. By mounting the differential directly to the body or frame, two short drive shafts can be used with an independent rear suspension to improve ride and handling. Independent RWD systems can use multiple control arms and trailing arms to limit unwanted lateral movements.



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**FIGURE 6-53** An example of an independent RWD suspension.

### TRACK BARS AND WATT'S LINKS

Many rear suspensions with dead axles use a track bar or Panhard bar. **Figure 6-54** shows a track bar attached to a rear axle on a RWD vehicle. The **track bar** is used to limit front and rear movement of the rear axle.

Some RWD vehicles use a Watt's link instead of a track bar. Found on some Ford and Dodge products, the Watt's link is also used to limit rear axle motion from side to side. An example of a Watt's link is shown in **Figure 6-55**.



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**FIGURE 6-54** The track bar is used to control body movements caused by the rear suspension moving.



**FIGURE 6-55** Watt's links are used to reduce body movements caused by the rear suspension moving.

## Electronic Suspension Systems

Electronic suspension systems have been in use for many years. Basic systems use a ride height sensor and air-adjustable shocks or air springs to increase ride height as vehicle load increases. Newer vehicles go beyond this, using magnetorheological fluid in the shocks and active roll stabilization to greatly enhance ride quality and handling.

### PURPOSE OF ELECTRONIC SUSPENSION SYSTEMS

Electronic suspension systems are now available on many vehicles, though they are most often found on luxury sport sedans and sport cars. The current generation of electronic suspensions are different than those found on older vehicles. Older systems used air springs to improve ride and to compensate for vehicle loading and ride height changes. Modern systems use advanced electronics and computer systems to make real-time changes to the steering and suspension systems to provide increased handling and safety.

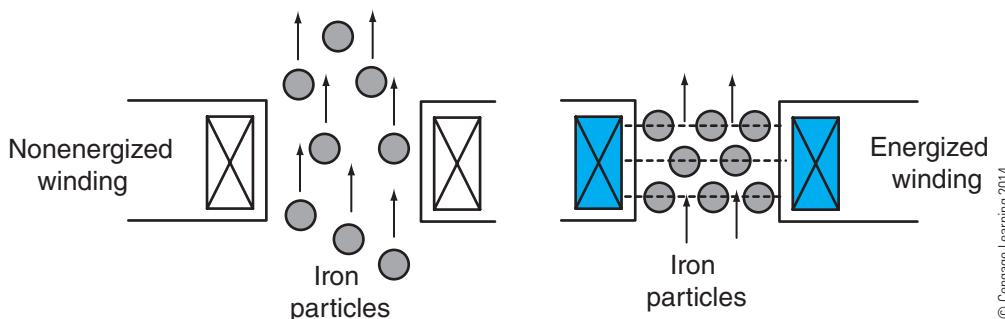
## TYPES OF ELECTRONIC SUSPENSION SYSTEMS

In the 1980s and 1990s, many large front- and rear-wheel drive cars had electronically operated air ride suspensions. Instead of traditional rear coil or leaf springs, air springs were used. By having an on-board air compressor and mounting a ride height sensor to the rear suspension, a module could detect changes in ride height and increase or decrease air pressure in the rear springs as needed. For example, if additional passengers and weight were added to the rear of the vehicle, the ride height would drop. The ride height sensor would detect this change and report to the control module. The module would then activate the air compressor to increase the air pressure in the springs, which would raise the rear of the vehicle back to the desired height. When the additional load was removed, the module would then deflate the air springs as necessary.

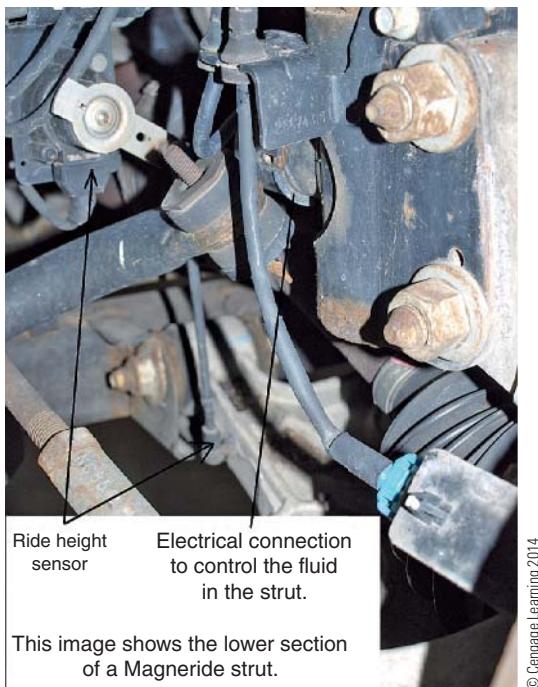
Some vehicles used a similar system at all four wheels, using air spring struts. The ride height of the entire vehicle could then be changed. This system would often lower the vehicle ride height above a certain speed to improve aerodynamics.

In the 1990s, Delphi introduced Magneride. Magneride uses a magnetorheological fluid in the shock absorbers. Basically, a magnetorheological fluid has magnetic properties; it is like an oil with a very fine metallic dust added. Since magnetic fields can be controlled, the Magneride system controls the viscosity of the fluid in the shocks. By allowing the fluid to be easier or more difficult to flow through the shock's valves, the ride quality can be changed. **Figure 6-56** shows a simplified version of how this system works.

By employing a network of sensors, the ride control system monitors vehicle performance and operating conditions. **Figure 6-57** and **Figure 6-58** show two examples of Magneride struts and shocks. Under normal driving conditions, the fluid in the shocks allows for normal, gentle cushioning for a smooth ride. If the road becomes rough, the system detects this and can change how the shock will operate in about five milliseconds, fast enough to change how the shock will respond while the wheel



**FIGURE 6-56** The fluid in the shock can be allowed to pass freely or be restricted. This changes the resistance of the shock and how the vehicle rides.



**FIGURE 6-57** Adaptive and active suspensions use sensors to transmit suspension movement information to the on-board computer system.

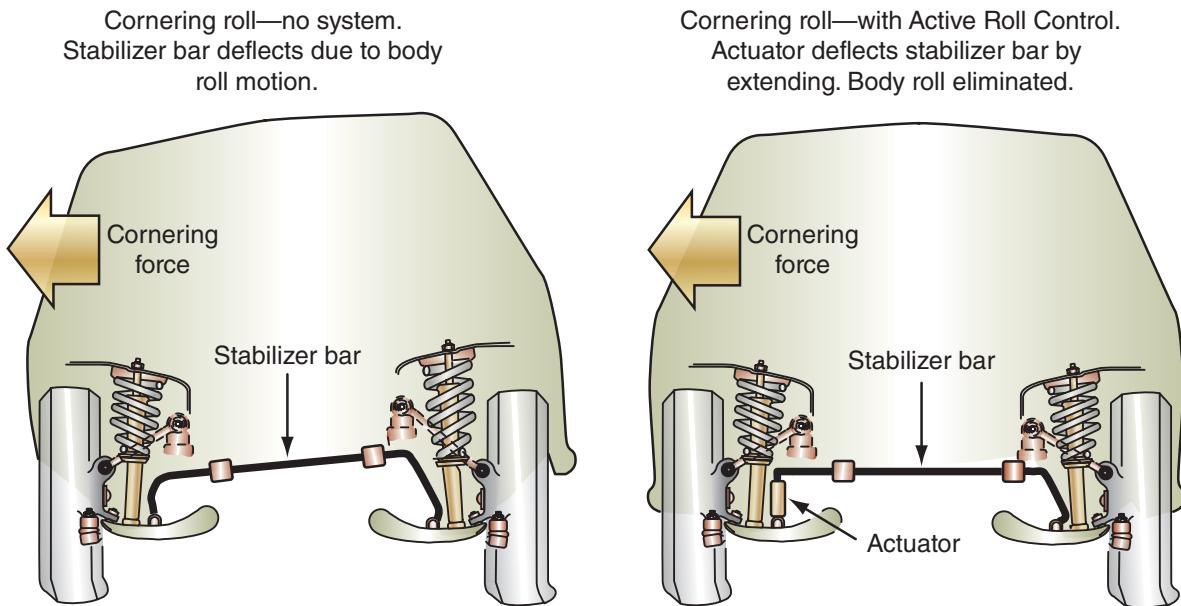
and tire are still negotiating the bump or dip in the road surface. Another advantage of this system is that it allows for selectable suspension operation. The driver can select a soft, smooth ride, or by merely moving a switch, select a firm, sporty feel that improves vehicle handling.

Modern vehicles may use either adaptive or active suspension systems. Adaptive systems monitor the vehicle and road conditions and adapt to maintain ride quality.



**FIGURE 6-58** This shock has the ability to change its resistance and damping qualities based on driving conditions and driver settings.

These systems are typically less complex and less expensive than active systems and do not perform functions such as reducing body roll when cornering. Active systems use more sensors and can not only adjust shock damping but also reduce body roll and can work with brake, steering, and powertrain systems to correct for driver error and help keep the vehicle under control. An example of active suspension system function is shown in **Figure 6-59**.



**FIGURE 6-59** Active suspension systems can adapt and change how a vehicle is riding and cornering in real time.

## SUMMARY

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The suspension system carries vehicle weight, reduces road shocks, and provides safe handling and a comfortable ride.

Independent suspensions allow each wheel to move without affecting the other wheels.

When one wheel on a dependent suspension axle moves over a bump, the tire on the opposite side also moves.

Oversteer is when the rear of the vehicle loses traction and causes the rear of the vehicle to slide during a corner.

Understeer is when the front tires lose traction and the vehicle continues to travel in a line that does not follow the path of a turn.

Sprung weight is the weight carried by the springs.

Unsprung weight is weight that is not carried by the springs.

Shock absorbers are used to dampen spring bounce or oscillations.

Ball joints located on the same control arm as a spring are load-carrying ball joints.

Stabilizer bars are used to reduce body roll and lean when cornering.

MacPherson struts combine a coil spring, shock, and upper pivot into one unit.

Modified strut suspensions relocate the spring away from the strut.

Short/long arm suspension, while once the most common, are now used mostly on large RWD vehicles.

Changing wheel and tire size on a vehicle can cause unwanted handling and steering consequences.

Modern luxury and high-performance sports cars often have electronic suspension systems that can adapt to road conditions.

## REVIEW QUESTIONS

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1. Springs \_\_\_\_\_ energy when compressed and \_\_\_\_\_ energy when they rebound.
2. The \_\_\_\_\_ design has a frame attached to the body with rubber mounts.
3. Used on most passenger cars today, the \_\_\_\_\_ type of construction provides a very rigid and strong frame.
4. The type of suspension that uses a strut with upper and lower control arms is the \_\_\_\_\_ suspension.
5. Shock absorbers act as \_\_\_\_\_ to reduce spring oscillations.
6. Which of the following is not an advantage of a rear dead axle?
  - a. Low cost
  - b. Simple design
  - c. Improved handling
  - d. Durability
7. Technician A says most FWD vehicles have a tendency to oversteer when making hard turns. Technician B says oversteer causes the vehicle to turn less sharply than the driver is turning the wheel. Who is correct?
  - a. Technician A
  - b. Technician B
  - c. Both A and B
  - d. Neither A nor B
8. The load-carrying ball joint in a short/long arm system is located where?
  - a. On the control arm above the spring
  - b. On the control arm on which the spring is seated
  - c. Short/long arm systems do not use a load-carrying ball joint
  - d. None of the above
9. Technician A says the wheels and tires are unsprung weight. Technician B says the spring is unsprung weight. Who is correct?
  - a. Technician A
  - b. Technician B
  - c. Both A and B
  - d. Neither A nor B
10. Technician A says spring rate refers to how quickly a spring stops bouncing after compression and release. Technician B says spring rate is the total amount of weight the spring can safely carry. Who is correct?
  - a. Technician A
  - b. Technician B
  - c. Both A and B
  - d. Neither A nor B