CHAPTER 24
Suspension System Components and Operation
After studying Chapter 24, the reader will be able to:

1. Prepare for ASE Suspension and Steering (A4) certification test content area “B” (Suspension System Diagnosis and Repair).
2. List various types of suspensions and their component parts.
3. Explain how coil, leaf, and torsion bar springs work.
4. Describe how suspension components function to allow wheel movement up and down and provide for turning.
5. Describe how shock absorbers control spring forces.
KEY TERMS

- Air spring
- Anti-dive
- Anti-squat
- Ball joints
- Bulkhead
- Bump stop
- Center bolt
- Coil springs
- Composite leaf spring
- Control arms
- Cradle
- Full frame
- GVW
- Hooke's Law
- Independent suspension
- Insulators
- Kingpin
- Ladder frame
- Lateral links
- Leaf springs
- Load-carrying ball joint
- Mono leaf
- Non-load-carrying ball joint
- Perimeter frame
- Platforms
- Rebound clips
- Shackles
- Shock absorbers
- Space frame
- Spring pocket
- Spring rate
- Springs
- Sprung weight
- Stabilizer bars
- Steering knuckles
- Stress riser
- Strut rod
- Struts
- Stub-type frame
- Torsion bar
- Unit-body
- Unsprung weight
- Wheel rate
INTRODUCTION

- Street-driven cars and trucks use a suspension system to keep the tires on the road and to provide acceptable riding comfort.
- A vehicle with a solid suspension, or no suspension, would bounce off the ground when the tires hit a bump.
- If the tires are off the ground, even for a fraction of a second, loss of control is possible.
- The purpose of the suspension is to provide the vehicle with the following:
  - A smooth ride
  - Accurate steering
  - Responsive handling
  - Support for the weight of the vehicle
  - Maintenance of acceptable tire wear
Frame construction usually consists of channel-shaped steel beams welded and/or fastened together.

The frame of a vehicle supports all the “running gear” of the vehicle, including the engine, transmission, rear axle assembly (if rear-wheel drive), and all suspension components.

This frame construction, referred to as full frame, is so complete that most vehicles can usually be driven without the body.

Most trucks and larger rear-wheel-drive cars use a full frame.
FRAME CONSTRUCTION

- LADDER FRAME
- PERIMETER FRAME
- STUB-TYPE FRAMES
- UNIT-BODY CONSTRUCTION
- SPACE FRAME CONSTRUCTION
FIGURE 24–1 A typical truck frame is an excellent example of a ladder-type frame. The two side members are connected by a crossmember.
FIGURE 24–2 Rubber cushions used in body or frame construction isolate noise and vibration from traveling to the passenger compartment.
FIGURE 24–3 (a) Separate body and frame construction; (b) unitized construction: the small frame members are for support of the engine and suspension components. Many vehicles attach the suspension components directly to the reinforced sections of the body and do not require the rear frame section.
FIGURE 24–4 Welded metal sections create a platform that combines the body with the frame using unit-body construction.
What Does GVW Mean?

• **GVW, gross vehicle weight**, is the weight of the vehicle plus the weight of all passengers the vehicle is designed to carry (150 lb [68 kg] each), plus the maximum allowable payload or luggage load. **Curb weight** is the weight of a vehicle when wet, meaning with a full tank of fuel and all fluids filled, but without passengers or cargo (luggage). **Model weight** is the weight of a vehicle wet and with passengers.
Most salvage businesses that deal with wrecked vehicles use a reference book called the *Hollander Interchange Manual*. In this yearly publication, every vehicle part is given a number. If a part from another vehicle has the same Hollander number, then the parts are interchangeable.
PLATFORMS

• The **platform** of any vehicle is its basic size and shape.
• Various vehicles of different makes can share the same platform, and therefore many of the same drive train (engine, transmission, and final drive components) and suspension and steering components.
• A platform of a unit-body vehicle includes all major sheet-metal components that form the load-bearing structure of the vehicle, including the front suspension and engine-supporting sections.
• The area separating the engine compartment from the passenger compartment is called the **bulkhead**.
UNSPRUNG WEIGHT

- A suspension system has to be designed to allow the wheels to move up and down quickly over bumps and dips without affecting the entire weight of the car or truck.
  - In fact, the lighter the total weight of the components that move up and down, the better the handling and ride.
- This weight is called **unsprung weight**.
- **Sprung weight** is the term used to identify the weight of the car or truck that does *not* move up and down and is supported or *sprung* by the suspension.
TYPES OF SUSPENSIONS

- Early suspension systems on old horse wagons, buggies, and older vehicles used a solid axle for front and rear wheels.
  - If one wheel hit a bump, the other wheel was affected.
- Most vehicles today use a separate control-arm-type of suspension for each front wheel, which allows for movement of one front wheel without affecting the other front wheel.
  - This type of front suspension is called independent suspension.
TYPES OF SUSPENSIONS

FIGURE 24–5 Solid I-beam axle with leaf springs.
FIGURE 24–6 When one wheel hits a bump or drops into a hole, both left and right wheels are moved. Because both wheels are affected, the ride is often harsh and feels stiff.
FIGURE 24–7 A typical independent front suspension used on a rear-wheel-drive vehicle. Each wheel can hit a bump or hole in the road independently without affecting the opposite wheel.
A suspension **spring** serves two purposes.

- First, it acts as a buffer between the suspension and frame to absorb vertical wheel and suspension movement without passing it on to the frame.
- Second, each spring transfers part of the vehicle weight to the suspension component it rests on, which transfers it to the wheels.

**SPRING MATERIALS**
Hooke’s Law

Regardless of type, all suspensions use springs that share a common characteristic described by Hooke’s Law.

What this means is that when a coil spring (for example) is depressed 1 in., it pushes back with a certain force (in pounds), such as 400 pounds.

If the spring is depressed another inch, the force exerted by the spring is increased by another 400 pounds.

The spring rate or force constant for this spring is therefore “400 lb per inch,” usually symbolized by the letter K.
**FIGURE 24–8** This spring was depressed 4 inches due to a weight of 2,000 lb. This means that this spring has a spring rate (K) of 500 lb per inch (2000 / 4 in. = 500 lb./in.).
Coil springs are made of special round spring steel wrapped in a helix shape.

The strength and handling characteristics of a coil spring depend on the following:

- Coil diameter
- Number of coils
- Height of spring
- Diameter of the steel coil that forms the spring.
FIGURE 24–9 The spring rate of a coil spring is determined by the diameter of the spring and the diameter of the steel used in its construction plus the number of coils and the free length (height).
FIGURE 24–10 Coil spring ends are shaped to fit the needs of a variety of suspension designs.
COIL SPRINGS

- SPRING RATE
- SPRING FREQUENCY
- WHEEL RATE
- COIL SPRING MOUNTING
- SPRING COATINGS
FIGURE 24–11 A constant-rate spring compresses at the same rate regardless of the amount of weight that is applied.
FIGURE 24–12 Variable-rate springs come in a variety of shapes and compress more slowly as weight is applied.
FIGURE 24–13 Two springs, each with a different spring rate and length, can provide the same ride height even though the higher-rate spring will give a stiffer ride.
Does the Spring Rate Change as the Vehicle Gets Older?

FREQUENTLY ASKED QUESTION

- No, the spring rate of a spring does not change, but the spring load can change due to fatigue. The spring rate is the amount of force it takes to compress the spring 1 inch. The spring load is the amount of weight that a spring can support at any given compressed height. When a spring fatigues, the spring’s load capacity decreases and the vehicle will sag.
FIGURE 24–14 Stiffer springs bounce at a higher frequency than softer springs.
FIGURE 24–15 The wheel and arm act as a lever to compress the spring. The spring used on the top picture must be stiffer than the spring used on the strut-type suspension shown on the bottom because the length of the lever arm is shorter.
FIGURE 24–16 The spring cushion helps isolate noise and vibration from being transferred to the passenger compartment. (Courtesy of Cooper Automotive Company)
Don’t Cut Those Coil Springs!

TECH TIP

- Chassis service technicians are often asked to lower a vehicle. One method is to remove the coil springs and cut off half or more coils from the spring. While this will lower the vehicle, this method is generally not recommended for the following reasons:
  - A coil spring could be damaged during the cutting-off procedure, especially if a torch is used to do the cutting.
  - The spring will get stiffer when shortened, often resulting in a very harsh ride.
  - The amount the vehicle is lowered is less than the amount cut off from the spring. This is because as the spring is shortened, it becomes stiffer. The stiffer spring will compress less than the original.
Don’t Cut Those Coil Springs!

**FIGURE 24–17** This replacement coil spring is coated to prevent rust and corrosion and colored to help identify the spring and/or spring manufacturer.
LEAF SPRINGS

- **Leaf springs** are constructed of one or more strips of long, narrow spring steel.
- These metal strips, called leaves, are assembled with plastic or synthetic rubber insulators between the leaves, allowing for freedom of movement during spring operation.

**FIGURE 24–18** A typical leaf spring used on the rear of a pickup truck showing the plastic insulator between the leaves, which allows the spring to move without creating wear or noise.
FIGURE 24–19 A typical leaf spring installation. The longest leaf, called the main leaf, attaches to the frame through a shackle and a hanger.
FIGURE 24–20 All multileaf springs use a center bolt to not only hold the leaves together but also help retain the leaf spring in the center of the spring perch.
FIGURE 24–21 When a leaf spring is compressed, the spring flattens and becomes longer. The shackles allow for this lengthening. Rubber bushings are used in the ends of the spring and shackles to help isolate road noise from traveling into the passenger compartment.
FIGURE 24–22 Typical rear leaf-spring suspension of a rear-wheel-drive vehicle.
FIGURE 24–23 As the vehicle is loaded, the leaf spring contacts a section of the frame. This shortens the effective length of the spring, which makes it stiffer.
FIGURE 24–24 Many pickup trucks, vans, and sport utility vehicles (SUVs) use auxiliary leaf springs that contact the other leaves when the load is increased.
LEAF SPRINGS
COMPOSITE LEAF SPRINGS

- Since the early 1980s, fiberglass-reinforced epoxy plastic composite leaf springs have been used on production vehicles.
- They save weight: An 8-pound spring can replace a conventional 40-pound steel leaf spring.

**FIGURE 24–25** (a) A fiberglass spring is composed of long fibers locked together in an epoxy (resin) matrix.
FIGURE 24–25 (b) When the spring compresses, the bottom of the spring expands and the top compresses. Composite leaf springs are used and mounted transversely (side-to-side) on Chevrolet Corvettes and at the rear on some other General Motors vehicles.
TORSION BARS

• A torsion bar is a spring that is a long, *round*, hardened steel bar similar to a coil spring except that it is a *straight* bar.

**FIGURE 24–26** A torsion bar resists twisting and is used as a spring on some cars and many four-wheel-drive pickup trucks and sport utility vehicles. The larger the diameter, or the shorter the torsion bar, the stiffer the bar. A torsion bar twists very little during normal operation and about a 1/16 of a revolution during a major suspension travel event.
TORSION BARS

- One end is attached to the lower control arm of a front suspension and the other end to the frame.
- When the wheels hit a bump, the bar twists and then untwists.

FIGURE 24–27 Longitudinal torsion bars attach at the lower control arm at the front and at the frame at the rear of the bar.
TORSION BARS

- As with all automotive springs, spring action is controlled by the shock absorbers.

- Unlike other types of springs, torsion bars may be adjustable for correct ride height.

FIGURE 24–28 One end of the torsion bar attaches to the lower control arm and the other to an anchor arm that is adjustable.
SUSPENSION PRINCIPLES

- Suspensions use various links, arms, and joints to allow the wheels to move freely up and down; front suspensions also have to allow the front wheels to turn.
- All suspensions must provide for the following supports:
  - Transverse (or side-to-side) wheel support
  - Longitudinal (front-to-back) wheel support
FIGURE 24–29 The spindle supports the wheels and attaches to the control arm with ball-and-socket joints called ball joints. The control arm attaches to the frame of the vehicle through rubber bushings to help isolate noise and vibration between the road and the body. (Courtesy of Cooper Automotive Company)
FIGURE 24–30 The strut rods provide longitudinal support to the suspension to prevent forward or rearward movement of the control arms.
SUSPENSION PRINCIPLES

- The design of the suspension and the location of the suspension mounting points on the frame or body are critical to proper vehicle handling.
- Two very important design factors are called **anti-squat** and **anti-dive**.
  - Anti-squat
  - Anti-dive
A steering knuckle is hard to classify either as part of the suspension or as part of the wheel.

A knuckle serves two purposes:

- To join the suspension to the wheel
- Usually includes the spindle where the front wheel bearings are attached
- To provide pivot points between the suspension and wheel.
FIGURE 24–31 The steering knuckle used on a short/long-arm front suspension.
A kingpin is a steel shaft or pin that joins the steering knuckle to the suspension and allows the steering knuckle to pivot.
CONTROL ARMS

- A **control arm** is a suspension link that connects a knuckle or wheel flange to the frame.
- One end of a control arm attaches to the knuckle or wheel flange, generally with either a ball joint or bushing.
- The opposite end of the arm, which attaches to a frame member, usually pivots on a bushing.
CONTROL ARMS

FIGURE 24–33 Control arms are used to connect the steering knuckle to the frame or body of the vehicle and provide the structural support for the suspension system.
Ball joints are actually ball-and-socket joints, similar to the joints in a person’s shoulder.

Ball joints allow the front wheels to move up and down, as well as side to side (for steering).

A vehicle can be equipped with coil springs, mounted either above the upper control arm or on the lower control arm.
FIGURE 24–34 Ball joints provide the freedom of movement necessary for steering and suspension movements.
FIGURE 24–35 The upper ball joint is load carrying in this type of suspension because the weight of the vehicle is applied through the spring, upper control arm, and ball joint to the wheel. The lower control arm is a lateral link, and the lower ball joint is called a follower ball joint.
The lower ball joint is load carrying in this type of suspension because the weight of the vehicle is applied through the spring, lower control arm, and ball joint to the wheel.

**FIGURE 24–36**
BALL JOINTS
BALL JOINT DESIGN

- There are two basic designs of ball joints: compression loaded and tension loaded.
- If the control arm rests on the steering knuckle, the ball joint is *compressed* into the control arm by the weight of the vehicle.
- If the knuckle rests on the control arm, the weight of the vehicle tends to pull the ball joint back into the control arm by *tension*.
- The type used is determined by the chassis design engineer, and the service technician cannot change the type of ball joint used for a particular application.
**BALL JOINTS**

**BALL JOINT DESIGN**

**FIGURE 24–37** All ball joints, whether tension or compression loaded, have a bearing surface between the ball stud and socket.
STRUT RODS

- Some vehicles are equipped with round steel rods that are attached between the lower control arm at one end and the frame of the vehicle with rubber bushings, called strut rod bushings, at the other end.
- The purpose of these strut rods is to provide forward/backward support to the control arms.
- Strut rods are used on vehicles equipped with MacPherson struts and many short/long-arm-type suspensions.
STRUT RODS

A strut rod is the longitudinal support to prevent front-to-back wheel movement. Strut rods are only used when there is only one lower control arm bushing and not used where there are two lower control arm bushings.
FIGURE 24–39 Strut rod bushings insulate the steel bar from the vehicle frame or body.
STABILIZER BARS

• Most cars and trucks are equipped with a **stabilizer bar** on the front suspension, which is a round, hardened steel bar (usually SAE 4560 or 4340 steel) attached to both lower control arms with bolts and rubber bushing washers called stabilizer bar bushings.
FIGURE 24–40 Typical stabilizer bar installation.
FIGURE 24–41 As the body of the vehicle leans, the stabilizer bar is twisted. The force exerted by the stabilizer bar counteracts the body lean.
FIGURE 24–42 Stabilizer bar links are sold as a kit consisting of the long bolt with steel sleeve and rubber bushings. Steel washers are used on both sides of the rubber bushings as shown.
FIGURE 24–43 Notice how the stabilizer bar pulls down on the mounting bushing when the vehicle is hoisted off the ground, allowing the front suspension to drop down. These bushings are a common source of noise, especially when cold. Lubricating the bushings with paste silicone grease often cures the noise.
Shock absorbers are used on all conventional suspension systems to dampen and control the motion of the vehicle’s springs.

Without shock absorbers (dampers), the vehicle would continue to bounce after hitting bumps.

**FIGURE 24-44** (a) Movement of the vehicle is supported by springs without a dampening device. (b) Spring action is dampened with a shock absorber. (c) The function of any shock absorber is to dampen the movement or action of a spring, similar to using a liquid to control the movement of a weight on a spring (d).
Shock absorbers work best when mounted as close to the spring as possible. Shock absorbers that are mounted straight up and down offer the most dampening.
FIGURE 24–46 When a vehicle hits a bump in the road, the suspension moves upward. This is called compression or jounce. Rebound is when the spring (coil, torsion bar, or leaf) returns to its original position.
SHOCK ABSORBERS

SHOCK ABSORBER OPERATION

- The hydraulic shock absorber operates on the principle of fluid being forced through a small opening (orifice).
FIGURE 24–47 (a) A cutaway drawing of a typical double-tube shock absorber. (b) Notice the position of the intake and compression valve during rebound (extension) and compression.
FIGURE 24–48 Oil flow through a deflected disc-type piston valve. The deflecting disc can react rapidly to suspension movement. For example, if a large bump is hit at high speed, the disc can deflect completely and allow the suspension to reach its maximum jounce distance while maintaining a controlled rate of movement.
SHOCK ABSORBERS
GAS-CHARGED SHOCKS

• Most shock absorbers on new vehicles are gas charged.
• Pressurizing the oil inside the shock absorber helps smooth the ride over rough roads.
  • This pressure helps prevent air pockets from forming in the shock absorber oil as it passes through the small passages in the shock.
• After the oil is forced through small passages, the pressure drops and the oil expands.
  • As the oil expands, bubbles are created.
  • The oil becomes foamy.
  • This air-filled oil does not effectively provide dampening.
  • The result of all of this aeration (air being mixed with the oil) is lack of dampening and a harsh ride.
Gas-charged shock absorbers are manufactured with a double-tube design similar to conventional shock absorbers and with a single or monotube design.
**SHOCK ABSORBERS**

**AIR SHOCKS/STRUTS**

- Air-inflatable shock absorbers or struts are used in the rear of vehicles to provide proper vehicle ride height while carrying heavy loads.
- Many air shock/strut units are original equipment.
- They are often combined with a built-in air compressor and ride height sensor(s) to provide automatic ride height control.
- Air-inflatable shocks are standard shock absorbers with an air chamber with a rubber bag built into the dust cover (top) of the shock.
What Are Remote Reservoir Shocks?

FREQUENTLY ASKED QUESTION

- Remote reservoir shock absorbers are units designed for heavy-duty use that use a separate container for the working fluid.
- The purpose of the remote fluid reservoir is to keep the temperature of the fluid stable, which helps the shock absorber provide consistent dampening under all conditions.
What Are Remote Reservoir Shocks?

**FIGURE 24–50** The shock absorber is on the right and the fluid reservoir for the shock is on the left.
FIGURE 24–51 A rubber tube forms an inflatable air chamber at the top of an air shock. The higher the air pressure in the chamber, the stiffer the shock.
Some electronically controlled suspension systems use air springs.

A basic *air spring* consists of a rubber air chamber, generally closed at the bottom by a piston fitted into a control arm, or by a strut shock absorber.
FIGURE 24–52 (a) The front suspension of a Lincoln with an air-spring suspension. (b) Always check in the trunk for the cutoff switch for a vehicle equipped with an air suspension before hoisting or towing the vehicle.
FIGURE 24–53 Some air springs are auxiliary units to the coil spring and are used to control ride height while the coil spring is the weight-bearing unit.
• COIL-OVER SHOCKS

**FIGURE 24–54** A coil-over shock is a standard hydraulic shock absorber with a coil spring wrapped around it to increase stiffness and/or take some of the carrying weight off of the springs.
STRUTS

- A **strut** is a sturdy shock absorber that is also a structural component of the suspension.
  - A strut is a suspension link as well as a shock absorber.
  - The casing of a strut must be strong and rigid to function as a suspension link.
  - The shock absorber assembles inside the casing of a strut, and may be either a removable cartridge or an integral part of the strut.

- **MACPHERSON STRUTS**
- **MODIFIED STRUTS**
A strut is a structural part of the suspension and includes the spring and shock absorber in one assembly.
FIGURE 24–56 A modified strut used on the rear suspension; it is part of the structural part of the assembly.
BUMP STOPS

- All suspension systems have a limit of travel.
  - If the vehicle hits a large bump in the road, the wheels are forced upward toward the vehicle with tremendous force.
  - This force is absorbed by the springs of the suspension system.
  - If the bump is large enough, the suspension is compressed to its mechanical limit.
  - Instead of allowing the metal components of the suspension to hit the frame or body of the vehicle, a rubber or foam bumper is used to absorb and isolate the suspension from the frame or body.
FIGURE 24–57 Suspension bumpers are used on all suspension systems to prevent metal-to-metal contact between the suspension and the frame or body of the vehicle when the suspension “bottoms out” over large bumps or dips in the road.
What Is a Track Rod?

What Is a Track Rod?

A track rod, also called a Panhard rod, is used in the rear of some suspension systems to keep the rear axle centered under the center of the vehicle. It is a straight rod or channel that connects to the frame on one end and the axle on the other end.
SUMMARY

1. The lighter the wheel/tire combination, the lower the unsprung weight and the better the ride and handling of the vehicle.

2. All springs—including the coil, leaf, and torsion bar types—share Hooke’s Law, which states that the force exerted by the spring is directly proportional to the amount the spring is deflected.

3. All springs are similar to torsion bars. As the torsion bar becomes longer or smaller in diameter, it becomes easier to twist. If a coil spring is cut, the remaining spring is shorter, yet stiffer.
4. Ball joints attach to control arms and allow the front wheels to move up and down, as well as turn.

5. Suspension designs include a straight or solid-axle, two control-arm-type called an SLA or a MacPherson strut.

6. All shock absorbers dampen the motion of the suspension to control ride and handling.
REVIEW QUESTIONS

1. List the types of suspensions and name their component parts.
2. Explain Hooke’s Law.
3. Describe the purpose and function of a stabilizer bar.
4. Explain the difference between a load-carrying and a friction ball joint.
1. The spring rate of a spring is measured in units of _______.
   a. lb per inch
   b. ft-lb
   c. PSI
   d. in.-lb
2. Two technicians are discussing torsion bars. Technician A says that many torsion bars are adjustable to allow for ride height adjustment. Technician B says that torsion bars are usually marked left and right and should not be switched side to side. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
3. What component(s) is considered to be unsprung weight?
   a. Frame
   b. Body
   c. Wheels and tires
   d. Both a and b
4. Two technicians are discussing MacPherson struts. Technician A says that in most applications the entire strut assembly rotates when the front wheels are turned. Technician B says a typical MacPherson strut suspension system uses only one control arm and one ball joint per side. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
CHAPTER QUIZ

5. Technician A says that regular replacement shock absorbers will raise the rear of a vehicle that is sagging down. Technician B says that replacement springs will be required to restore the proper ride height. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
6. What suspension component is used to counteract body lean during cornering?
   a. Torsion bar
   b. Strut rod
   c. Stabilizer bar
   d. Control arm
7. A center bolt is used in what type of spring?
   a. Coil
   b. Leaf
   c. Torsion bar
   d. All of the above
CHAPTER QUIZ

8. Two technicians are discussing air shocks. Technician A says that air is forced through small holes to dampen the ride. Technician B says that air shocks are conventional hydraulic shock absorbers with an airbag to control vehicle ride height. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
9. The owner of a pickup truck wants to cut the coil springs to lower the vehicle. Technician A says that the ride will be harsher than normal if the springs are cut. Technician B says that the springs could be damaged, especially if a cutting torch is used to cut the springs. Which technician is correct?

a. Technician A only
b. Technician B only
c. Both Technicians A and B
d. Neither Technician A nor B
10. A MacPherson strut is a structural part of the vehicle.
   a. True
   b. False