TODAY'S TECHNICIAN™

Shop Manual for

Automotive Brake Systems

Fourth Edition

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Automotive Brake Systems

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Clifton E. Owen
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Griffin, GA

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PREFACE

Thanks to the support the Today's Technician™ series has received from those who teach automotive technology, Thomson Delmar Learning, the leader in automotive related textbooks, is able to live up to its promise to provide new editions of the series regularly. We have listened and responded to our critics and our fans and present this new updated and revised fourth edition. By revising our series regularly, we can and will respond to changes in the industry, changes in technology, changes in the certification process, and to the ever-changing needs of those who teach automotive technology.

The Today's Technician™ series, by Thomson Delmar Learning, features textbooks that cover all mechanical and electrical systems of automobiles and light trucks (whereas the Heavy-duty Trucks portion of the series does the same for Heavy-duty vehicles). Principally, the individual titles correspond to the main areas of ASE (National Institute for Automotive Service Excellence) certification. Additional titles include remedial skills and theories common to all of the certification areas and advanced or specific subject areas that reflect the latest technological trends. Each text is divided into two volumes: a Classroom Manual and a Shop Manual.

Unlike yesterday's mechanic, the technician of today and for the future must know the underlying theory of all automotive systems and be able to service and maintain those systems. Dividing the material into two volumes provides the reader with the information needed to begin a successful career as an automotive technician without interrupting the learning process by mixing cognitive and performance learning objectives into one volume.

The design of Thomson Delmar Learning's Today's Technician™ series was based on features that are known to promote improved student learning. The design was further enhanced by a careful study of survey results, in which the respondents were asked to value particular features. Some of these features can be found in other textbooks, whereas others are unique to this series.

Each Classroom Manual contains the principles of operation for each system and subsystem. The Classroom Manual also contains discussions on design variations of key components used by the different vehicle manufacturers. This volume is organized to build on basic facts and theories. The primary objective of this volume is to allow the reader to gain an understanding of how each system and subsystem operates. This understanding is necessary to diagnose the complex automobiles of today and tomorrow. Although the basics contained in the Classroom Manual provide the knowledge needed for diagnostics, diagnostic procedures appear only in the Shop Manual. An understanding of the basics is also a requirement for competence in the skill areas covered in the Shop Manual.

A spiral-bound Shop Manual covers the "how-to's." This volume includes step-by-step instructions for diagnostic and repair procedures. Photo Sequences are used to illustrate some of the common service procedures. Other common procedures are listed and are accompanied with line drawings and photos that allow the reader to visualize and conceptualize the finest details of the procedure. This volume also contains the reasons for performing the procedures as well as when that particular service is appropriate.

The two volumes are designed to be used together and are arranged in corresponding chapters. Not only are the chapters in the volumes linked together, but also the contents of the chapters are linked. This linking of content is evidenced by marginal callouts that refer the reader to the chapter and page that the same topic is addressed in the other volume. This feature is valuable to instructors. Without this feature, users of other two-volume textbooks must search the index or table of contents to locate supporting information in the other volume. This is not only cumbersome but also creates additional work for an instructor when planning the presentation of material and when making reading assignments. It is also valuable to the students; with page references, they also know exactly where to look for supportive information.

Both volumes contain clear and thoughtfully selected illustrations, many of which are original drawings or photos specially prepared for inclusion in this series. This means that the art is a vital part of each textbook and not merely inserted to increase the numbers of illustrations.

The page layout, used in the series, is designed to include information that would otherwise break up the flow of information presented to the reader. The main body of the text includes all of the "need-to-know" information and illustrations. In the wide side margins of each page are many of the special features of the series. Items that are truly "nice-to-know" information include simple examples of concepts just introduced in the text, explanations or definitions of terms that will not be defined in the glossary, examples of common trade jargon used to describe a part or operation, and exceptions to the norm explained in the text. Many textbooks attempt to include this type of information and insert it in the main body of text; this tends to interrupt the thought process and cannot be pedagogically justified. By placing this information off to the side of the main text, the reader can select when to refer to it.

Highlights of This Edition—Classroom Manual

The text and figures of this edition are updated to show modern brake technology and applications. The Classroom Manual covers the complete mechanical-hydraulic automotive braking theories. It introduces the reader to the first generation of electric brake systems with a brief overview of brake-by-wire applications in the first chapter. The following chapters cover basic brake physics theories; discussion of newer components and materials, including a section on electric parking brakes; and any braking functions required for passenger cars and light trucks. The reader is introduced to fundamental information on trailer brakes and the DOT requirements for trailer brakes. In the trailer section electric, electrohydraulic, and surge-braking systems are discussed. A new Chapter 10 in this text entitled Electrical Braking Systems (EBS) simplifies the discussion on traditional antilock brake systems (ABS) while retaining the information for a complete understanding of ABS. This chapter guides the reader from ABS through traction control and the incorporation of those systems, to vehicle stability systems. Electrohydraulic brakes are discussed in detail along with straightforward information on vehicle stability fundamentals. The Classroom Manual guides the reader from traditional hydraulic brakes to the brake system of the future.

Highlights of This Edition—Shop Manual

Safety information has been moved from the Classroom Manual to the first chapter of the Shop Manual. This places this critical subject next to the work to be accomplished. Chapter 2, Brake Service Tools and Equipment, covers basic tools with more information on brake special tools and equipment. Some of the safety information that is pertinent to a particular piece of equipment has been moved to this chapter so safety issues are presented just before operation of the equipment. Another major improvement is that the related system information is presented in Chapter 3 instead of the last chapter. This is more in accordance with standard brake operation and diagnosis procedures. Totally new information covers diagnosing electric parking brakes and electric braking systems. To clarify the diagnosis and repair procedures for electric braking two major ABS/TCS brands, Delphi DBC-7 and Teves Mark 20E, are used for discussion instead of the complete industry as in the last edition. This helps the reader better understand the technical diagnosing and repairing for all ABS/TCS. This edition of the Shop Manual will guide the student/technician through all the basic tasks in brake system repair.

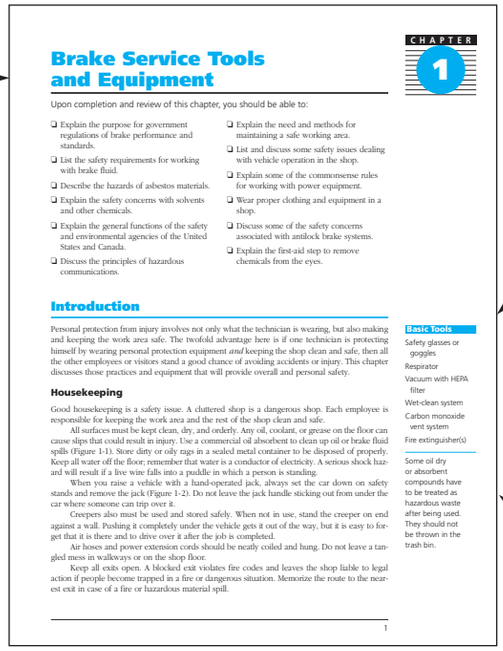
Shop Manual

To stress the importance of safe work habits, the Shop Manual dedicates one full chapter to safety. Other important features of this manual include:

Performance Objectives

These objectives define the contents of the chapter and define what the student should have learned on completion of the chapter.

Although this textbook is not designed simply to prepare someone for the certification exams, it is organized around the ASE task list. These tasks are defined generically when the procedure is commonly followed and specifically when the procedure is unique for specific vehicle models. Imported and domestic model automobiles and light trucks are included in the procedures.



CHAPTER 1

Brake Service Tools and Equipment

Upon completion and review of this chapter, you should be able to:

- ❑ Explain the purpose for government regulations of brake performance and standards.
- ❑ List the safety requirements for working with brake fluid.
- ❑ Describe the hazards of asbestos materials.
- ❑ Explain the safety concerns with solvents and other chemicals.
- ❑ Explain the general functions of the safety and environmental agencies of the United States and Canada.
- ❑ Discuss the principles of hazardous communications.
- ❑ Explain the need and methods for maintaining a safe working area.
- ❑ List and discuss some safety issues dealing with vehicle operation in the shop.
- ❑ Explain some of the commonsense rules for working with power equipment.
- ❑ Wear proper clothing and equipment in a shop.
- ❑ Discuss some of the safety concerns associated with antilock brake systems.
- ❑ Explain the first-aid step to remove chemicals from the eyes.

Introduction

Personal protection from injury involves not only what the technician is wearing, but also making and keeping the work area safe. The twofold advantage here is if one technician is protecting himself by wearing personal protection equipment *and* keeping the shop clean and safe, then all the other employees or visitors stand a good chance of avoiding accidents or injury. This chapter discusses those practices and equipment that will provide overall and personal safety.

Housekeeping

Good housekeeping is a safety issue. A cluttered shop is a dangerous shop. Each employee is responsible for keeping the work area and the rest of the shop clean and safe.

All surfaces must be kept clean, dry, and orderly. Any oil, coolant, or grease on the floor can cause slips that could result in injury. Use a commercial oil absorbent to clean up oil or brake fluid spills (Figure 1-1). Store dirty or oily rags in a sealed metal container to be disposed of properly. Keep all water off the floor; remember that water is a conductor of electricity. A serious shock hazard will result if a live wire falls into a puddle in which a person is standing.

When you raise a vehicle with a hand-operated jack, always set the car down on safety stands and remove the jack (Figure 1-2). Do not leave the jack handle sticking out from under the car where someone can trip over it.

Creepers also must be used and stored safely. When not in use, stand the creeper on end against a wall. Pushing it completely under the vehicle gets it out of the way, but it is easy to forget that it is there and to drive over it after the job is completed.

Air hoses and power extension cords should be neatly coiled and hung. Do not leave a tangled mess in walkways or on the shop floor.

Keep all exits open. A blocked exit violates fire codes and leaves the shop liable to legal action if people become trapped in a fire or dangerous situation. Memorize the route to the nearest exit in case of a fire or hazardous material spill.

1

Basic Tools

Safety glasses or goggles
Respirator
Vacuum with HEPA filter
Wet-clean system
Carbon monoxide vent system
Fire extinguisher(s)

Some oil dry or absorbent compounds have to be treated as hazardous waste after being used. They should not be thrown in the trash bin.

Tools Lists

Each chapter begins with a list of the Basic Tools needed to perform the tasks included in the chapter. Whenever a Special Tool is required to complete a task, it is listed in the margin next to the procedure.

Marginal Notes

Page numbers for cross-referencing appear in the margin. Some of the common terms used for components, and other bits of information, also appear in the margin. These marginal notes provide an understanding of the language of the trade and help when conversing with an experienced technician.

Photo Sequences

Many procedures are illustrated in detailed Photo Sequences. These detailed photographs show the students what to expect when they perform particular procedures. They also can provide a student a familiarity with a system or type of equipment that the school may not have.

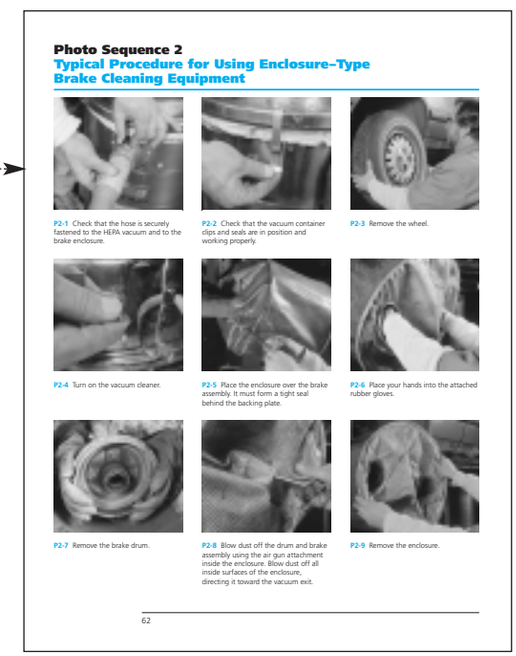


Photo Sequence 2
Typical Procedure for Using Enclosure–Type Brake Cleaning Equipment

P2-1 Check that the hose is securely fastened to the HEPA vacuum and to the brake enclosure.

P2-2 Check that the vacuum container clips and seals are in position and working properly.

P2-3 Remove the wheel.

P2-4 Turn on the vacuum cleaner.

P2-5 Place the enclosure over the brake assembly. It must form a tight seal behind the backing plate.

P2-6 Place your hands into the attached rubber gloves.

P2-7 Remove the brake drum.

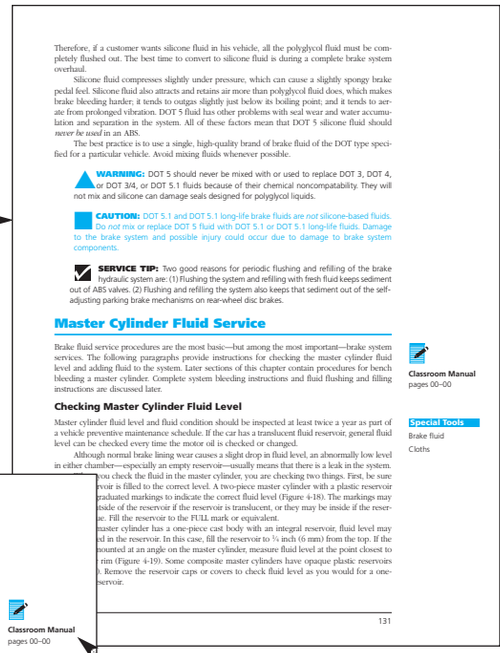
P2-8 Blow dust off the drum and brake assembly using the air gun attachment inside the enclosure. Blow dust off all inside surfaces of the enclosure, directing it toward the vacuum exit.

P2-9 Remove the enclosure.

62

Service Tips

Whenever a special procedure is appropriate, it is described in the text. These tips are generally those things commonly done by experienced technicians.



Therefore, if a customer wants silicone fluid in his vehicle, all the polyglycol fluid must be completely flushed out. The best time to convert to silicone fluid is during a complete brake system overhaul.

Silicone fluid compresses slightly under pressure, which can cause a slightly spongy brake pedal feel. Silicone fluid also attracts and retains air more than polyglycol fluid does, which makes brake bleeding harder; it tends to outgas slightly just below its boiling point; and it tends to aerate from prolonged vibration. DOT 5 fluid has other problems with seal wear and water accumulation and separation in the system. All of these factors mean that DOT 5 silicone fluid should *never be used* in an ABS.

The best practice is to use a single, high-quality brand of brake fluid of the DOT type specified for a particular vehicle. Avoid mixing fluids whenever possible.

WARNING: DOT 5 should never be mixed with or used to replace DOT 3, DOT 4, or DOT 3/4, or DOT 5.1 fluids because of their chemical noncompatability. They will not mix and silicone can damage seals designed for polyglycol liquids.

CAUTION: DOT 5.1 and DOT 5.1 long-life brake fluids are *not* silicone-based fluids. *Do not* mix or replace DOT 5 fluid with DOT 5.1 or DOT 5.1 long-life fluids. Damage to the brake system and possible injury could occur due to damage to brake system components.

SERVICE TIP: Two good reasons for periodic flushing and refilling of the brake hydraulic system are: (1) Flushing the system and refilling with fresh fluid keeps sediment out of ABS valves. (2) Flushing and refilling the system also keeps that sediment out of the self-adjusting parking brake mechanisms on rear-wheel disc brakes.

Master Cylinder Fluid Service

Brake fluid service procedures are the most basic—but among the most important—brake system services. The following paragraphs provide instructions for checking the master cylinder fluid level and adding fluid to the system. Later sections of this chapter contain procedures for bench bleeding a master cylinder. Complete system bleeding instructions and fluid flushing and filling instructions are discussed later.

Checking Master Cylinder Fluid Level

Master cylinder fluid level and fluid condition should be inspected at least twice a year as part of a vehicle preventive maintenance schedule. If the car has a translucent fluid reservoir, general fluid level can be checked every time the motor oil is checked or changed.

Although normal brake lining wear causes a slight drop in fluid level, an abnormally low level in either chamber—especially an empty reservoir—usually means that there is a leak in the system.

you check the fluid in the master cylinder, you are checking two things. First, be sure
voir is filled to the correct level. A two-piece master cylinder with a plastic reservoir
graduated markings to indicate the correct fluid level (Figure 4-18). The markings may
side of the reservoir if the reservoir is translucent, or they may be inside if the reser-
ae. Fill the reservoir to the FULL mark or equivalent.
master cylinder has a one-piece cast body with an integral reservoir, fluid level may
ed in the reservoir. In this case, fill the reservoir to ¼ inch (6 mm) from the top. If the
mounted at an angle on the master cylinder, measure fluid level at the point closest to
rim (Figure 4-19). Some composite master cylinders have opaque plastic reservoirs
). Remove the reservoir caps or covers to check fluid level as you would for a one-
servoir.

Classroom Manual
pages 00–00

Special Tools
Brake fluid
Cloths

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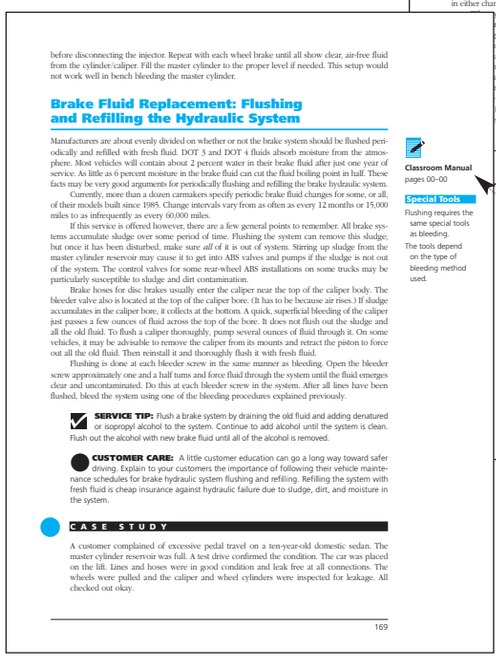
Cautions and Warnings

Throughout the text, cautions are given to alert the reader to potentially hazardous materials or unsafe conditions. Warnings are also given to advise the student of things that can go wrong if instructions are not followed or if an unacceptable part or tool is used.



before disconnecting the injector. Repeat with each wheel brake until all show clear, air-free fluid from the cylinder/caliper. Fill the master cylinder to the proper level if needed. This setup would not work well in bench bleeding the master cylinder.

Brake Fluid Replacement: Flushing and Refilling the Hydraulic System

Manufacturers are about evenly divided on whether or not the brake system should be flushed periodically and refilled with fresh fluid. DOT 3 and DOT 4 fluids absorb moisture from the atmosphere. Most vehicles will contain about 2 percent water in their brake fluid after just one year of service. As little as 6 percent moisture in the brake fluid can cut the fluid boiling point in half. These facts may be very good arguments for periodically flushing and refilling the brake hydraulic system.

Currently, more than a dozen carmakers specify periodic brake fluid changes for some, or all, of their models built since 1985. Change intervals vary from as often as every 12 months or 15,000 miles to as infrequently as every 60,000 miles.

If this service is offered however, there are a few general points to remember. All brake systems accumulate sludge over some period of time. Flushing the system can remove this sludge; but once it has been disturbed, make sure *all* of it is out of system. Stirring up sludge from the master cylinder reservoir may cause it to get into ABS valves and pumps if the sludge is not out of the system. The control valves for some rear-wheel ABS installations on some trucks may be particularly susceptible to sludge and dirt contamination.

Brake hoses for disc brakes usually enter the caliper near the top of the caliper body. The bleeder valve also is located at the top of the caliper bore. (It has to be because air rises.) If sludge accumulates in the caliper bore, it collects at the bottom. A quick, superficial bleeding of the caliper just passes a few ounces of fluid across the top of the bore. It does not flush out the sludge and all the old fluid. To flush a caliper thoroughly, pump several ounces of fluid through it. On some vehicles, it may be advisable to remove the caliper from its mounts and retract the piston to force out all the old fluid. Then reinstall it and thoroughly flush it with fresh fluid.

Flushing is done at each bleeder screw in the same manner as bleeding. Open the bleeder screw approximately one and a half turns and force fluid through the system until the fluid emerges clear and uncontaminated. Do this at each bleeder screw in the system. After all lines have been flushed, bleed the system using one of the bleeding procedures explained previously.

SERVICE TIP: Flush a brake system by draining the old fluid and adding denatured or isopropyl alcohol to the system. Continue to add alcohol until the system is clean. Flush out the alcohol with new brake fluid until all of the alcohol is removed.

CUSTOMER CARE: A little customer education can go a long way toward safer driving. Explain to your customers the importance of following their vehicle maintenance schedules for brake hydraulic system flushing and refilling. Refilling the system with fresh fluid is cheap insurance against hydraulic failure due to sludge, dirt, and moisture in the system.

CASE STUDY

A customer complained of excessive pedal travel on a ten-year-old domestic sedan. The master cylinder reservoir was full. A test drive confirmed the condition. The car was placed on the lift. Lines and hoses were in good condition and leak free at all connections. The wheels were pulled and the caliper and wheel cylinders were inspected for leakage. All checked out okay.

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Classroom Manual
pages 00–00

Special Tools
Flushing requires the same special tools as bleeding.
The tools depend on the type of bleeding method used.

References to the Classroom Manual

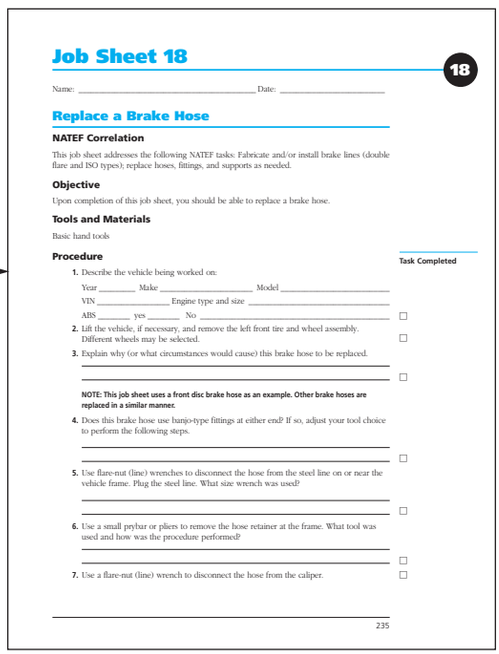
Reference to the appropriate page in the Classroom Manual is given whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Classroom Manual may be fundamental to the topic discussed in the Shop Manual.

Customer Care

This feature highlights those little things a technician can do or say to enhance customer relations.

Job Sheets

Located at the end of each chapter, the Job Sheets provide a format for students to perform procedures covered in the chapter. A reference to the ASE and NATEF Tasks addressed by the procedure is referenced on the Job Sheet.



Job Sheet 18

18

Name: _____ Date: _____

Replace a Brake Hose

NATEF Correlation

This job sheet addresses the following NATEF tasks: Fabricate and/or install brake lines (double flare and ISO types); replace hoses, fittings, and supports as needed.

Objective

Upon completion of this job sheet, you should be able to replace a brake hose.

Tools and Materials

Basic hand tools

Procedure

Task Completed

1. Describe the vehicle being worked on:
   Year _____ Make _____ Model _____
   VIN _____ Engine type and size _____
   ABS _____ yes _____ No _____ ☐
2. Lift the vehicle, if necessary, and remove the left front tire and wheel assembly. Different wheels may be selected. ☐
3. Explain why (or what circumstances would cause) this brake hose to be replaced. ☐

NOTE: This job sheet uses a front disc brake hose as an example. Other brake hoses are replaced in a similar manner.

4. Does this brake hose use banjo-type fittings at either end? If so, adjust your tool choice to perform the following steps. ☐
5. Use flare-nut (line) wrenches to disconnect the hose from the steel line on or near the vehicle frame. Plug the steel line. What size wrench was used? ☐
6. Use a small prybar or pliers to remove the hose retainer at the frame. What tool was used and how was the procedure performed? ☐
7. Use a flare-nut (line) wrench to disconnect the hose from the caliper. ☐

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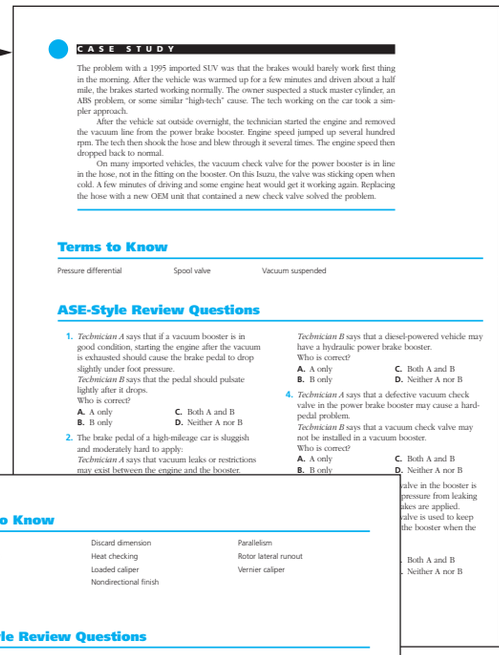
Case Studies

Case Studies concentrate on the ability to properly diagnose the systems. Chapters 3 through 10 end with a case study in which a vehicle has a problem, and the logic used by a technician to solve the problem is explained.



CASE STUDY

The problem with a 1995 imported SUV was that the brakes would barely work first thing in the morning. After the vehicle was warmed up for a few minutes and driven about a half mile, the brakes started working normally. The owner suspected a stuck master cylinder, an ABS problem, or some similar "high-tech" cause. The tech working on the car took a simpler approach.

After the vehicle sat outside overnight, the technician started the engine and removed the vacuum line from the power brake booster. Engine speed jumped up several hundred rpm. The tech then shook the hose and blew through it several times. The engine speed then dropped back to normal.

On many imported vehicles, the vacuum check valve for the power booster is in line in the hose, not in the fitting on the booster. On this Isuzu, the valve was sticking open when cold. A few minutes of driving and some engine heat would get it working again. Replacing the hose with a new OEM unit that contained a new check valve solved the problem.

Terms to Know

Pressure differential Spool valve Vacuum suspended

ASE-Style Review Questions

1. *Technician A* says that if a vacuum booster is in good condition, starting the engine after the vacuum is exhausted should cause the brake pedal to drop slightly under foot pressure.
Technician B says that the pedal should pulsate lightly after it drops.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

2. The brake pedal of a high-mileage car is sluggish and moderately hard to apply:
Technician A says that vacuum leaks or restrictions may exist between the engine and the booster.
Technician B says that a diesel-powered vehicle may have a hydraulic power brake booster.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

4. *Technician A* says that a defective vacuum check valve in the power brake booster may cause a hard-pedal problem.
Technician B says that a vacuum check valve may not be installed in a vacuum booster.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

alve in the booster is pressure from leaking akes are applied. alve is used to keep the booster when the

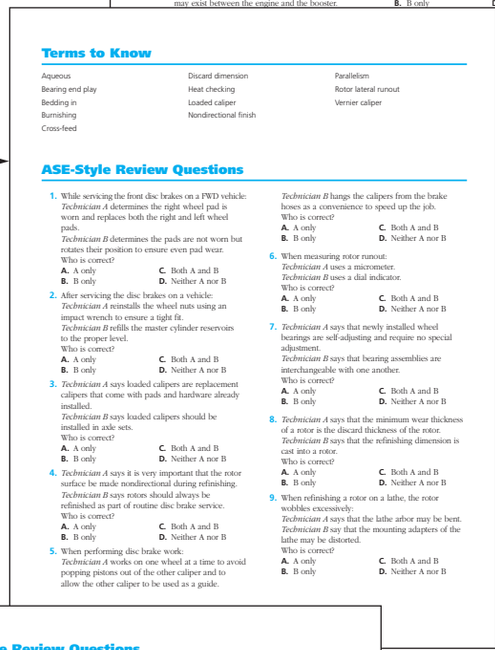
Both A and B
Neither A nor B

Terms to Know

Terms in this list can be found in the Glossary at the end of the manual.

ASE-Style Review Questions

Each chapter contains ASE-style review questions that reflect the performance objectives listed at the beginning of the chapter. These questions can be used to review the chapter as well as to prepare for the ASE certification exam.



Terms to Know

Aqueous
Bearing end play
Bedding in
Burnishing
Cross-feed
Discard dimension
Heat checking
Loaded caliper
Nondirectional finish
Parallelism
Rotor lateral runout
Vernier caliper

ASE-Style Review Questions

1. While servicing the front disc brakes on a FWD vehicle:
Technician A determines the right wheel pad is worn and replaces both the right and left wheel pads.
Technician B determines the pads are not worn but rotates their position to ensure even pad wear.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

2. After servicing the disc brakes on a vehicle:
Technician A reinstalls the wheel nuts using an impact wrench to ensure a tight fit.
Technician B refills the master cylinder reservoirs to the proper level.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

3. *Technician A* says loaded calipers are replacement calipers that come with pads and hardware already installed.
Technician B says louded calipers should be installed in axle sets.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

4. *Technician A* says it is very important that the rotor surface be made nondirectional during refinishing.
Technician B says rotors should always be refinished as part of routine disc brake service.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

5. When performing disc brake work:
Technician A works on one wheel at a time to avoid popping pistons out of the other caliper and to allow the other caliper to be used as a guide.
Technician B hangs the calipers from the brake hoses as a convenience to speed up the job.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

6. When measuring rotor runout:
Technician A uses a micrometer.
Technician B uses a dial indicator.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

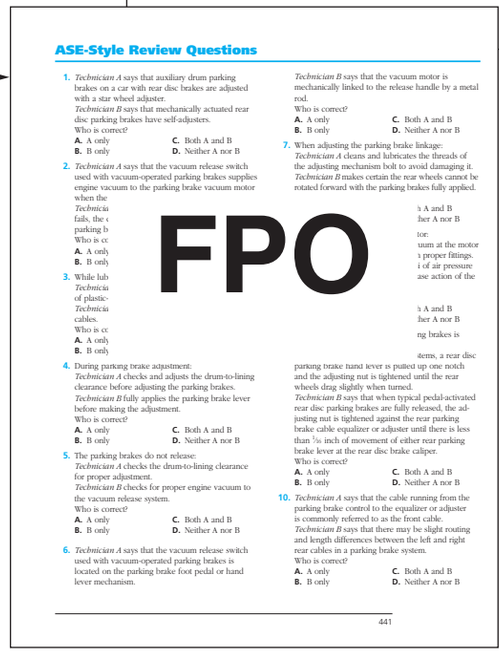
7. *Technician A* says that newly installed wheel bearings are self-adjusting and require no special adjustment.
Technician B says that bearing assemblies are interchangeable with one another.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

8. *Technician A* says that the minimum wear thickness of a rotor is the discard thickness of the rotor.
Technician B says that the refinishing dimension is cast into a rotor.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

9. When refinishing a rotor on a lathe, the rotor wobbles excessively:
Technician A says that the lathe arbor may be bent.
Technician B say that the mounting adapters of the lathe may be distorted.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

ASE Practice Examination

A 50-question ASE practice exam, located in the Appendix, is included to test students on the content of the complete Shop Manual.



ASE-Style Review Questions

1. *Technician A* says that auxiliary drum parking brakes on a car with rear disc brakes are adjusted with a star wheel adjuster.
Technician B says that mechanically actuated rear disc parking brakes have self-adjusters.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

2. *Technician A* says that the vacuum release switch used with vacuum-operated parking brakes supplies engine vacuum to the parking brake vacuum motor when the
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fails, the
parking b
Who is co
A. A only
B. B only

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B. B only

4. During parking brake adjustment:
Technician A checks and adjusts the drum-to-lining clearance before adjusting the parking brakes.
Technician B fully applies the parking brake lever before making the adjustment.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

5. The parking brakes do not release:
Technician A checks the drum-to-lining clearance for proper adjustment.
Technician B checks for proper engine vacuum to the vacuum release system.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

6. *Technician A* says that the vacuum release switch used with vacuum-operated parking brakes is located on the parking brake foot pedal or hand lever mechanism.
Technician B says that the vacuum motor is mechanically linked to the release handle by a metal rod.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

7. When adjusting the parking brake linkage:
Technician A cleans and lubricates the threads of the adjusting mechanism bolt to avoid damaging it.
Technician B makes certain the rear wheels cannot be rotated forward with the parking brakes fully applied.

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ems, a rear disc parking brake hand lever is pulled up one notch and the adjusting nut is tightened until the rear wheels drag slightly when turned.
Technician B says that when typical pedal-activated rear disc parking brakes are fully released, the adjusting nut is tightened against the rear parking brake cable equalizer or adjuster until there is less than 5/16 inch of movement of either rear parking brake lever at the rear disc brake caliper.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

10. *Technician A* says that the cable running from the parking brake control to the equalizer or adjuster is commonly referred to as the front cable.
Technician B says that there may be slight routing and length differences between the left and right rear cables in a parking brake system.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

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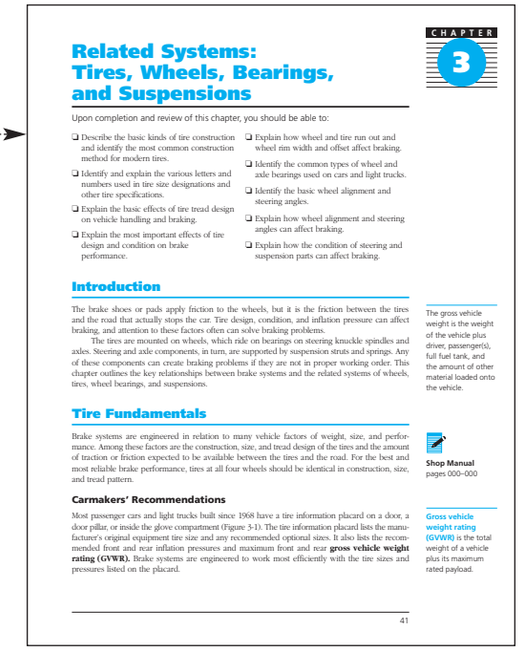
Classroom Manual

Features of this manual include:

Cognitive Objectives

These objectives define the contents of the chapter and define what the student should have learned on completion of the chapter.
Each topic is divided into small units to promote easier understanding and learning.



CHAPTER 3

Related Systems: Tires, Wheels, Bearings, and Suspensions

Upon completion and review of this chapter, you should be able to:

- ❑ Describe the basic kinds of tire construction and identify the most common construction method for modern tires.
- ❑ Identify and explain the various letters and numbers used in tire size designations and other tire specifications.
- ❑ Explain the basic effects of tire tread design on vehicle handling and braking.
- ❑ Explain the most important effects of tire design and condition on brake performance.
- ❑ Explain how wheel and tire run out and wheel rim width and offset affect braking.
- ❑ Identify the common types of wheel and axle bearings used on cars and light trucks.
- ❑ Identify the basic wheel alignment and steering angles.
- ❑ Explain how wheel alignment and steering angles can affect braking.
- ❑ Explain how the condition of steering and suspension parts can affect braking.

Introduction

The brake shoes or pads apply friction to the wheels, but it is the friction between the tires and the road that actually stops the car. Tire design, condition, and inflation pressure can affect braking, and attention to these factors often can solve braking problems.

The tires are mounted on wheels, which ride on bearings on steering knuckle spindles and axles. Steering and axle components, in turn, are supported by suspension struts and springs. Any of these components can create braking problems if they are not in proper working order. This chapter outlines the key relationships between brake systems and the related systems of wheels, tires, wheel bearings, and suspensions.

The gross vehicle weight is the weight of the vehicle plus driver, passenger(s), full fuel tank, and the amount of other material loaded onto the vehicle.

Tire Fundamentals

Brake systems are engineered in relation to many vehicle factors of weight, size, and performance. Among these factors are the construction, size, and tread design of the tires and the amount of traction or friction expected to be available between the tires and the road. For the best and most reliable brake performance, tires at all four wheels should be identical in construction, size, and tread pattern.

Shop Manual pages 000–000

Carmakers' Recommendations

Most passenger cars and light trucks built since 1968 have a tire information placard on a door, a door pillar, or inside the glove compartment (Figure 3-1). The tire information placard lists the manufacturer's original equipment tire size and any recommended optional sizes. It also lists the recommended front and rear inflation pressures and maximum front and rear **gross vehicle weight rating (GVWR).** Brake systems are engineered to work most efficiently with the tire sizes and pressures listed on the placard.

Gross vehicle weight rating (GVWR) is the total weight of a vehicle plus its maximum rated payload.

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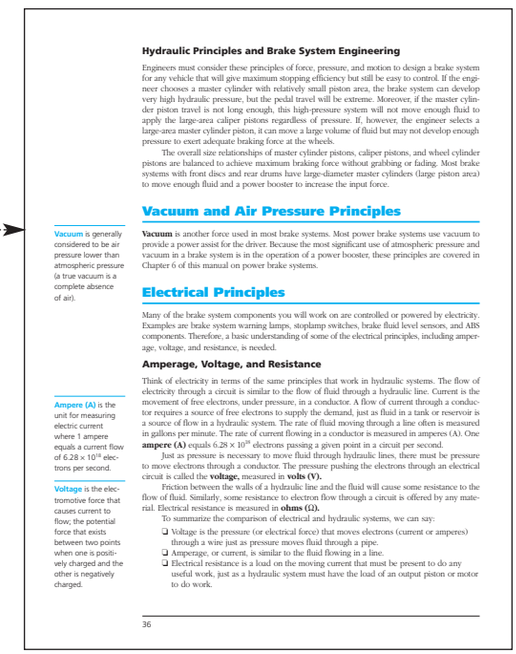
References to the Shop Manual

Reference to the appropriate page in the Shop Manual is given whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Shop Manual may be fundamental to the topic discussed in the Classroom Manual.

Marginal Notes

New terms are pulled out and defined. Common trade jargon also appears in the margin and gives some of the common terms used for components. These marginal notes allow the reader to speak and understand the language of the trade, especially when conversing with an experienced technician.



Hydraulic Principles and Brake System Engineering

Engineers must consider these principles of force, pressure, and motion to design a brake system for any vehicle that will give maximum stopping efficiency but still be easy to control. If the engineer chooses a master cylinder with relatively small piston area, the brake system can develop very high hydraulic pressure, but the pedal travel will be extreme. Moreover, if the master cylinder piston travel is not long enough, this high-pressure system will not move enough fluid to apply the large-area caliper pistons regardless of pressure. If, however, the engineer selects a large-area master cylinder piston, it can move a large volume of fluid but may not develop enough pressure to exert adequate braking force at the wheels.

The overall size relationships of master cylinder pistons, caliper pistons, and wheel cylinder pistons are balanced to achieve maximum braking force without grabbing or fading. Most brake systems with front discs and rear drums have large-diameter master cylinders (large piston area) to move enough fluid and a power booster to increase the input force.

Vacuum and Air Pressure Principles

Vacuum is generally considered to be air pressure lower than atmospheric pressure (a true vacuum is a complete absence of air).

Vacuum is another force used in most brake systems. Most power brake systems use vacuum to provide a power assist for the driver. Because the most significant use of atmospheric pressure and vacuum in a brake system is in the operation of a power booster, these principles are covered in Chapter 6 of this manual on power brake systems.

Electrical Principles

Many of the brake system components you will work on are controlled or powered by electricity. Examples are brake system warning lamps, stoplamp switches, brake fluid level sensors, and ABS components. Therefore, a basic understanding of some of the electrical principles, including amperage, voltage, and resistance, is needed.

Amperage, Voltage, and Resistance

Think of electricity in terms of the same principles that work in hydraulic systems. The flow of electricity through a circuit is similar to the flow of fluid through a hydraulic line. Current is the movement of free electrons, under pressure, in a conductor. A flow of current through a conductor requires a source of free electrons to supply the demand, just as fluid in a tank or reservoir is a source of flow in a hydraulic system. The rate of fluid moving through a line often is measured in gallons per minute. The rate of current flowing in a conductor is measured in amperes (A). One **ampere (A)** equals 6.28×10^{18} electrons passing a given point in a circuit per second.

Ampere (A) is the unit for measuring electric current where 1 ampere equals a current flow of 6.28×10^{18} electrons per second.

Just as pressure is necessary to move fluid through hydraulic lines, there must be pressure to move electrons through a conductor. The pressure pushing the electrons through an electrical circuit is called the **voltage,** measured in **volts (V).**

Voltage is the electromotive force that causes current to flow; the potential force that exists between two points when one is positively charged and the other is negatively charged.

Friction between the walls of a hydraulic line and the fluid will cause some resistance to the flow of fluid. Similarly, some resistance to electron flow through a circuit is offered by any material. Electrical resistance is measured in **ohms (Ω).**

To summarize the comparison of electrical and hydraulic systems, we can say:

- ❑ Voltage is the pressure (or electrical force) that moves electrons (current or amperes) through a wire just as pressure moves fluid through a pipe.
- ❑ Amperage, or current, is similar to the fluid flowing in a line.
- ❑ Electrical resistance is a load on the moving current that must be present to do any useful work, just as a hydraulic system must have the load of an output piston or motor to do work.

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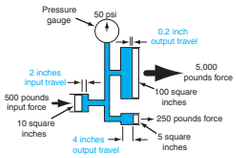

Figure 2-20 The output pistons' movement and their created force will be proportional to their size in relationship to the input piston size.

If the output piston is larger than the input piston, it exerts more force but travels a shorter distance. The opposite also is true. If the output piston is smaller than the input piston, it exerts less force but travels a longer distance. Apply the equation to the 5-square-inch output piston in Figure 2-20:

$$\frac{10 \text{ square inches (input piston)}}{5 \text{ square inches (output piston)}} = \frac{2}{1} \times 2 \text{ inches (input stroke)} = 4.0 \text{ inches output motion}$$

In this case, the smaller output piston applies only half the force of the input piston, but its stroke (motion) is twice as long.

This relationship of force, pressure, and motion in a brake system is shown when the force applied to the master cylinder pistons and the resulting brake force and piston movement at the wheels is considered. Wheel cylinder pistons move only a fraction of an inch to apply hundreds of pounds of force to the brake shoes, but the wheel cylinder piston travel is quite a bit less than the movement of the master cylinder piston. Disc brake caliper pistons move only a few thousandths of an inch but apply great force to the brake rotors.

A BIT OF HISTORY

All of the hydraulic principles that are applied in a brake system are based on the work of a seventeenth-century scientist named Blaise Pascal. Pascal's work is known as Pascal's law. Pascal's law says that pressure at any one point in a confined liquid is the same in every direction and applies equal force on equal areas.

One of the most important results of Pascal's work was the discovery that fluids can be used to increase force. Pascal was the first person to demonstrate the relationships of pressure, force, and motion and the inverse relationship of motion and force. On an automobile, Pascal's laws are applied not just to the brake system. These same hydraulic principles are at work in the hydraulic system of an automatic transmission and other systems. Pascal's laws are even at work in the movement of liquid fuel from a tank to the fuel-injection system on the engine.

A Bit of History

This feature gives the student a sense of the evolution of the automobile. This feature not only contains nice-to-know information, but also should spark some interest in the subject matter.

Summaries

Each chapter concludes with summary statements that contain the important topics of the chapter. These are designed to help the reader review the contents.

Summary

- ❑ Brake fluid specifications are defined by SAE Standard J1703 and FMVSS 116.
- ❑ Fluids are assigned DOT numbers: DOT 3, DOT 4, DOT 5, DOT 3/4, and DOT 5.1.
- ❑ Always use fluid with the DOT number recommended by any specific carmaker.
- ❑ Never use DOT 5 fluid in an ABS or mix with any other brake fluid.
- ❑ HSMO fluids are very rare and should never be used in brake systems designed for DOT fluids.
- ❑ The brake pedal assembly is a lever that increases pedal force to the master cylinder.
- ❑ The brake pedal lever is attached to a pushrod, which transmits force to the master cylinder pistons.
- ❑ The master cylinder has two main parts: a reservoir and a cylinder body.
- ❑ The reservoir can be a separate piece or cast as one piece with the cylinder.
- ❑ A dual-piston master cylinder has two separate pistons providing pressure for two independent hydraulic systems. Each of the two pistons in the master cylinder has a cup, a return spring, and a seal.
- ❑ During application, the piston and cup force fluid ahead of the piston to activate the brakes.
- ❑ During release, the return spring returns the piston.
- ❑ Fluid from the reservoir flows from the reservoir through the replenishing port around the piston cup.
- ❑ Excess fluid in front of the piston flows back into the reservoir through the vent ports.
- ❑ A front-to-rear split hydraulic system has two master cylinder circuits. One is connected to the front brakes and the other to the rear brakes.
- ❑ A diagonally split hydraulic system is one in which one master cylinder circuit is connected to the left front and right rear brakes and the other circuit is connected to the right front and left rear brakes.
- ❑ Quick take-up or fast-fill master cylinders have a step bore, which is a larger diameter bore for the rear section of the primary piston.
- ❑ Quick take-up master cylinders have a valve that provides rapid filling of the low-pressure spool area of the primary piston from the reservoir.
- ❑ Some ABS master cylinders have check valves in the heads of the pistons to reduce piston and pedal vibration and cup wear.

Terms to Know

Adjustable Pedal System (APS)
Cup seal
Diaphragm
Free play
Hydraulic system mineral oil (HSMO)
O-ring
Polyglycol
Quick take-up master cylinder
Quick take-up valve
Replenishing port
Reservoir
Residual pressure check valve
Vent port

Terms to Know

A list of new terms appears next to the Summary. Definitions for these terms can be found in the Glossary at the end of the manual.

Review Questions

Short answer essay, fill-in-the-blank, and multiple-choice questions follow each chapter. These questions are designed to accurately assess the student's competence in the stated objectives at the beginning of the chapter.

Review Questions

Short-Answer Essays

1. Identify and explain the systems of tire size designations and other tire specifications.
2. Describe the basic kinds of tire construction and identify the most common construction method for modern tires.
3. Explain the use of unidirectional tread pattern and its disadvantage compared to standard production tire tread.
4. Discuss run-flat tires.
5. List the basic adjustable wheel alignment and steering angles.
6. List the nonadjustable alignment and steering angles.
7. Identify the common types of wheel bearings used on cars and light trucks.
8. Explain how the condition of related systems may affect braking.
9. Identify the principal dimensions used to specify wheel size.
10. Explain the operational differences between WSB and PSB systems.

Fill in the Blanks

1. The steel beads around the rim and layers of cords or plies that are bonded together to give a tire its shape and strength are called the _____.
2. The layer of tire rubber that contacts the road and that contains a distinctive pattern is called the _____.
3. A tire with the cords in the body plies of the carcass running at an angle of 90 degrees to the steel beads in the inner rim of the carcass is a _____ _____ tire.
4. The _____ _____ is the percentage of tire cross-sectional height to cross-sectional width.
5. The most common system used to identify tires for passenger cars and many light trucks today is the _____ system.
6. On wet pavement, a slick tire will _____ on a layer of water trapped between the tread and the pavement.
7. The distance between the centerline of a rim and the mounting plane of the wheel is _____ _____.
8. The distance from the tire contact patch centerline to the point where the steering axis intersects the road is _____ _____.
9. The inward or outward tilt of the wheel measured from top to bottom and viewed from the front of the car is _____.
10. The backward or forward angle of the steering axis viewed from the side of the car is _____.

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Reviewers

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