Automotive Technology 6th Edition
Chapter 98 BRAKE HYDRAULIC SYSTEMS
Opening Your Class

KEY ELEMENT	EXAMPLES
Introduce Content	This Automotive Technology 6th text provides complete coverage of automotive components, operation, design, and troubleshooting. It correlates material to task lists specified by ASE and ASEEducation (NATEF) and emphasizes a problem-solving approach. Chapter features include Tech Tips, Frequently Asked Questions, Case Studies, Videos, Animations, and ASEEducation (NATEF) Task Sheets.
Motivate Learners	Explain how the knowledge of how something works translates into the ability to use that knowledge to figure why the engine does not work correctly and how this saves diagnosis time, which translates into more money.
State the learning objectives for the chapter or course you are about to cover and explain this is what they should be able to do as a result of attending this session or class.	Explain learning objectives to students as listed below: 1. Explain how the non-compressibility of liquids is used in brake systems. 2. State Pascal's law. 3. Describe the function, purpose, operation, and types of master cylinders. 4. Describe the process of diagnosing and troubleshooting master cylinders. 5. This chapter will help prepare for the Brakes (A5) ASE certification test content area "A" (Hydraulic, Power Assist, and Parking Brake Systems Diagnosis and Repair).
Establish the Mood or Climate	Provide a ***WELCOME,*** Avoid put downs and bad jokes.
Complete Essentials	Restrooms, breaks, registration, tests, etc.
Clarify and Establish Knowledge Base	Do a round robin of the class by going around the room and having each student give their backgrounds, years of experience, family, hobbies, career goals, or anything they want to share.

NOTE: Lesson plan is based on 6th Edition Chapter Images found on Jim's web site @ www.jameshalderman.com

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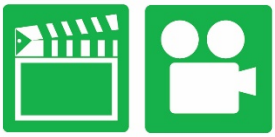
http://www.jameshalderman.com/automotive_principles.html

NOTE: You can use Chapter Images or possibly Power Point files:

ICONS	Chapter 98 Brake Hydraulics
	**1. SLIDE 1 CH98 BRAKE HYDRAULIC SYSTEMS** 2. **SLIDE 2 EXPLAIN Figure 98-1** Hydraulic brake lines transfer the brake effort to each brake assembly attached to all four wheels. 3. **SLIDE 3 EXPLAIN Figure 98-2** Because liquids cannot be compressed, they are able to transmit motion in a closed system. 4. **SLIDE 4 EXPLAIN Figure 98-3** Hydraulic system must be free of air to operate properly. If air is in system, air is compressed when brake pedal is depressed and brake fluid does not transmit the force to wheel brakes.
	**Check for ADDITIONAL VIDEOS & ANIMATIONS @ http://www.jameshalderman.com/** **WEB SITE IS CONSTANTLY UPDATED**
	**http://www.jameshalderman.com/automotive_principles.html** **DOWNLOAD** **Crossword Puzzle (Microsoft Word) (PDF)** **Word Search Puzzle (Microsoft Word) (PDF**
	**Videos**
 	**DISCUSSION: discuss the general principles of hydraulics or mechanical properties of fluids.**
	**DEMONSTRATION: Show pistons cannot compress liquids in closed system. Ask them to explain how air can contaminate hydraulic system & what problems result from such contamination** **Pascal's Law, Area (View) (Download)** **Pascal's Law, Force (View) (Download)** **Pascal's Law, Pressure (View) (Download)**
	5. **SLIDE 5 EXPLAIN Figure 98-4** one-pound force exerted on a small piston in sealed system transfers pressure to each square inch throughout system. In this example, 1-lb force is able to lift a 100-lb weight because it is supported by piston that is 100 x larger in area than small piston.
	6. **SLIDE 6 EXPLAIN Figure 98-5** amount of force (F) on the piston is the result of pressure (P) multiplied by the

surface area (A). In this example, the driver is applying a force of 150 pounds but through the mechanical advantage of the brake pedal (3.3 to 1 ratio), the force is increased to 500 pounds into master cylinder.

DISCUSS FREQUENTLY ASKED QUESTION: *How Much Brake Fluid Is Moved When the Brake Pedal Is Depressed?* During a typical brake application, only about 1 teaspoon (5 ml or cc) of brake fluid actually is moved from master cylinder and into hydraulic system to cause the pressure buildup to occur.

7. **SLIDE 7 EXPLAIN FIGURE 98–6** brake pad (friction material) is pressed on both sides of rotating rotor by the hydraulic pressure of the caliper.
8. **SLIDE 8 EXPLAIN FIGURE 98–7** Mechanical force and the master cylinder piston area determine the hydraulic pressure in the brake system..
9. **SLIDE 9 EXPLAIN FIGURE 98–8** Hydraulic pressure is the same throughout a closed system and acts with equal force on equal areas.
10. **SLIDE 10 EXPLAIN FIGURE 98–9 Differences in brake caliper and wheel cylinder piston area have a major effect on brake application force.**
11. **SLIDE 11 EXPLAIN FIGURE 98–10** The increase in application force created by large brake caliper piston is offset by a decrease in piston travel.
12. **SLIDE 12 EXPLAIN FIGURE 98–11** master cylinder showing the see-through reservoir and location of the brake fluid level sensor with a cutaway showing the internal pistons..

DISCUSS CASE STUDY: Bigger Is Not Better

DEMONSTRATION: Show students an application of Pascal's Law by demonstrating that a force applied to a piston in a sealed system displaces equal amounts of force in every direction. Use a single master cylinder & 2 wheel cylinders with different piston area measurements. Ask students to interpret results in accordance with

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	**Pascal's Law. How does this demonstration correspond to operation of a braking system?** **DISCUSSION: Ask student to talk about Pascal's Law and how it is the central principle upon which hydraulic systems work.**
	**DISCUSSION: Ask students to talk about the relationship between hydraulic pressure and piston size. Why does increasing the piston size reduce the hydraulic pressure achieved?**
	**Using clear medical syringes and clear plastic tubing can help students visualize hydraulic principles**
	**DISCUSSION: Ask students to discuss why, although mechanical force available to apply disc brakes is greater, the amount of hydraulic energy converted into mechanical motion is less. What are implications of this fact for disc-brake design?**
	**HANDS-ON TASK: Using equation below & textbook pages 1027-1031, have students calculate the movement of a disc-brake caliper when the area of the master-cylinder piston is 0.95 sq. in., the area of the wheel cylinder or caliper piston is 3.75 sq. in., and the master cylinder piston stroke length is 0.9 in. (*Answer*: 0.228 in.)** $d_1 = \frac{A_2}{A_1} d_2 \quad \frac{.95}{3.75} \times .9 = 0.228$
	**DISCUSSION: Ask students to talk about the implications of hydraulics for brake-system design. Have them focus on selection of correct piston size to provide driver with proper brake-pedal feel.**

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	**EXPLAIN TECH TIP:** ***Don't Fill the Master Cylinder without Seeing Me!*** **The boss explained to the beginning technician that there are two reasons why customer should be told not to fill master cylinder reservoir when brake fluid is down to the "minimum" mark, as shown in • FIGURE 98–12.** **1. If master cylinder reservoir is low, there may be a leak that should be repaired.** **1. 2. As the brakes wear, the disc brake piston moves outward to maintain the same distance between friction materials and the rotor. Therefore, as disc brake pads wear, the brake fluid level goes down to compensate. Therefore, if brake fluid is low, the vehicle should be serviced—either for new brakes or to repair a leak.**
	**13. SLIDE 13 EXPLAIN FIGURE 98–12** Master cylinder with brake fluid level at the "max" (maximum) line. **14. SLIDE 14 EXPLAIN FIGURE 98–13** typical brake pedal is supported by a mount and attached to the pushrod by a U-shaped bracket. The pin used to retain clevis to brake pedal is usually called a clevis pin.. **15. SLIDE 15 EXPLAIN FIGURE 98–14** cutaway of a master cylinder. The reservoir feeds both chambers and uses a fluid level switch that activates red brake warning lamp if the brake fluid level drops too low**.** **16. SLIDE 26 EXPLAIN FIGURE 98–15** Note various names for **vent port (front port)** and **replenishing port (rear port).** Names vary by vehicle and brake component manufacturer. Vent port and replenishing port are terms recommended by SAE. **17. SLIDE 17 EXPLAIN FIGURE 98–16 vent ports must remain open to allow brake fluid to expand** when heated by the friction material and transferred to the caliper and/or wheel cylinder. As brake fluid increases in temperature, it expands. Heated brake fluid can expand and flow back into the reservoir through vent ports. **18. SLIDE 18 EXPLAIN FIGURE 98–17** As brake pedal is depressed, the pushrod moves primary piston forward, **closing off vent port**. As soon as port is blocked, pressure builds in front of primary sealing cup, which pushes on the secondary piston. Secondary piston also

moves forward, blocking the secondary vent port and building pressure in front of sealing cup.

19. **SLIDE 19 EXPLAIN FIGURE 98–18 purpose of replenishing port is to keep volume behind primary piston filled with brake fluid from reservoir** as piston moves forward during a brake application..
20. **SLIDE 20 EXPLAIN FIGURE 98–19** When brake pedal is released, master cylinder piston moves rearward. Some of brake fluid is pushed back up through replenishing port, but most of fluid flows past the sealing cup. Therefore, when the driver pumps the brake pedal, the additional fluid in front of the pressure-building sealing cup is available quickly**.**
21. **SLIDE 21 EXPLAIN FIGURE 98–20** Rear-wheel-drive vehicles use a dual split master cylinder**.**
22. **SLIDE 22 EXPLAIN FIGURE 98–21** primary outlet is closest to the pushrod end of the master cylinder and the secondary outlet is closest to nose end of master cylinder.
23. **SLIDE 23 EXPLAIN FIGURE 98–22** In event of a primary system failure, no hydraulic pressure is available to push the second piston forward. As a result, primary piston extension contacts secondary piston and pushes on the secondary piston mechanically, rather than hydraulically. The loss of pressure in primary system is usually noticed by driver by a lower-than-normal brake pedal and lighting of the red brake warning lamp..
24. **SLIDE 24 EXPLAIN FIGURE 98–23** Front-wheel-drive vehicles use a diagonal split master cylinder. In this design, one section of the master cylinder operates right front and left rear brake and other section operates left front and right rear. In event of a failure in one section, at least one front brake still functions.

EXPLAIN TECH TIP: *Too Much Is Bad:* Some vehicle owners or inexperienced service people may fill master cylinder to top. Master cylinders should only be filled to "maximum" level line or about 1/4 inch (6 mm) from top to allow room for expansion when the brake fluid gets hot during normal operation. If the master cylinder is filled to top, expanding brake fluid has no place to expand and can leak out of top of reservoir. The spilled brake fluid removes paint and can cause corrosion of any electrical wiring or

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	**Components located under master cylinder.** **EXPLAIN TECH TIP: *Always Check for Venting (Compensation)* Whenever diagnosing any braking problem, start the diagnosis at the master cylinder—the heart of any braking system. Remove the reservoir cover and observe brake fluid for spurting while an assistant depresses brake pedal.** **• Normal operation (movement of fluid observed in reservoir) There should be a squirt or movement of brake fluid out of the vent port of both the primary and secondary chambers. This indicates that the vent port is open and that the sealing cup is capable of moving fluid upward through the port before the cup seals off port as it moves forward to pressurize fluid.**
	**Show ANIMATION: Brake Hydraulic System (View) (Download)**
	**DEMONSTRATION: Show students the master cylinder of a vehicle, and ask them to describe how it works. Why is the master cylinder the heart of the braking system? Show students the see-through reservoir of a master cylinder, and point out the minimum and maximum fill markings**
	**Never fill the master cylinder higher than the recommended full mark to allow for brake-fluid expansion.**
	**DEMONSTRATION: Show master cylinder when brakes are not applied, or in the at-rest position. Discuss how brake-fluid expansion and contraction can occur with changes in temperature. Show students what changes occur within the master cylinder when brakes are applied, and ask them to explain the results. Show students what changes occur within master cylinder when brakes are released & returned to at-rest position. What is impact of pumping brakes?**
	**If mineral based fluids (motor oil or hydraulic fluid) have been introduced to the brake system the rubber diaphragm will**

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	**swell over sized. This will show that there are extensive repairs to be made.** **DISCUSSION: discuss purpose and function of vent and replenishing ports in the master cylinder. How is outside air and moisture prohibited from entering the master cylinder through these vents?**
	**25. SLIDE-25 EXPLAIN FIGURE 98–24** Quick take-up master cylinder can be identified by the oversize primary low-pressure chamber.
	**DEMONSTRATION: Show an example of a diagonal-split master cylinder, and discuss how it enables front and rear braking action in the event of the failure of one cylinder**
	**DISCUSSION: what % of braking that would be supplied in the event that one half of a diagonally split brake system fails.**
	**When hydraulic switch turns light on during ½ of system failure light switch may have to be re-centered manually to get light off**
	**EXPLAIN TECH TIP: *Brake Pedal Depressor Trick*** **The master cylinder can be used to block the flow of brake fluid. Whenever any hydraulic brake component is removed, brake fluid tends to leak out because the master cylinder is usually higher than most other hydraulic components, such as wheel cylinders and calipers. To prevent brake fluid loss that can easily empty master cylinder reservoir, simply depress the brake pedal slightly or prop a stick or other pedal depressor to keep brake pedal down. When the brake pedal is depressed, piston sealing cups move forward, blocking off the reservoir from the rest of the braking system. The master cylinder stays full and the brake fluid stops dripping out of brake lines that have been disconnected. • SEE FIGURE 98–25.**

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	**26. SLIDE 26 EXPLAIN FIGURE 98-25** brake pedal depressor like this can be used during a wheel alignment to block the flow of brake fluid from the master cylinder during service work on the hydraulic system **27. SLIDE 27 EXPLAIN. Figure 98-26** Some seepage is normal when trace of fluid appears on the vacuum booster shell.
	**OPTIONAL DEMONSTRATION: Show students an example of a QUICK TAKE-UP master cylinder if one is available.**
	**DEMONSTRATION: Show student how to check for proper fluid movement in the master cylinder reservoir.**
	HANDS-ON TASK: Have students perform a visual inspection of a master cylinder. Have students check position & operation of brake pedal following inspection. Select a student to present results of inspection to class, identifying any problems & suggesting possible causes & solutions.
	**EXPLAIN TECH TIP: *Quick and Easy Brake Reserve Test.* Brake pedal reserve distance can be easily checked by depressing brake pedal with right foot and attempting to slide your left foot under the brake pedal. • SEE FIGURE 98–27.**
	**28. SLIDE 28 EXPLAIN FIGURE 98–27** Pedal height is usually measured from the floor to top of brake pedal. Always follow OEM recommended procedures and measurements. **29. SLIDE 29 EXPLAIN FIGURE 98–28** Pedal height is usually measured from the floor to the top of the brake pedal. Always follow the OEMS procedures and measurements. **30. SLIDE 30 EXPLAIN FIGURE 98–29** Brake pedal free play is the distance between brake pedal fully released and the position of the brake pedal when braking resistance is felt. **31. SLIDE 31 EXPLAIN FIGURE 98–30** Measure unapplied distance between brake pedal & steering wheel.

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  Education Foundation  	**DEMONSTRATION: Show students how to check brake pedal free play. Explain the importance of this specification.** **ON-VEHICLE ASEEDUCATION TASK: Measure brake pedal height; determine necessary action.** **Brake fluid is highly corrosive. Always use fender covers to protect the vehicle's finish from contact with brake fluid.** 32. **SLIDE 32 EXPLAIN FIGURE 98–31** Apply brakes and measure distance again. 33. **SLIDE 33 EXPLAIN FIGURE 98-32** Using a prybar to carefully remove reservoir from the master cylinder. 34. **SLIDE 34 EXPLAIN FIGURE 98–33** Piston assembly. 35. **SLIDE 35 EXPLAIN Figure 98-34** To reinstall the reservoir onto a master cylinder, place the reservoir on a clean flat surface and push the housing down onto the reservoir after coating the rubber seals with brake fluid. 36. **SLIDE 36 EXPLAIN Figure 98-35** Bleeding a master cylinder before installing it on the vehicle. The master cylinder is clamped into a bench vise while using a rounded end of a dowel rod to push on the pushrod end with bleeder tubes down into the brake fluid. Master cylinders should be clamped on the mounting flange as shown to prevent distorting the master cylinder bore. 37. **SLIDE 37 EXPLAIN Figure 98-36** Installing a master cylinder. Always tighten the retaining fastener and brake lines to factory specifications. **WARNING Use extreme care when using compressed air. Piston can be shot out of master cylinder with a great force, which could cause personal injury.** **DISCUSSION: Ask students to discuss how to diagnose and correct spongy brake pedal. Ask how to test & fix a lower-than-normal brake pedal. Ask students to discuss how to diagnose and correct a problem that would cause a brake pedal to go all the way to the floor. Ask students to talk about the**
 	

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	phenomenon of bypassing, or internal leak within the master cylinder. How can a technician determine an external leak within braking system versus bypassing within master cylinder? **EXPLAIN TECH TIP:** ***Key Steps When Installing a Master Cylinder:*** **Install master cylinder retaining bolts loosely so that master cylinder is free to move. This allows movement of master cylinder while threading the brake-line fittings to master cylinder. Align each brake-line fitting to proper port and tighten finger tight. The fittings should screw in a number of turns before it stops. Do NOT force fittings into the master cylinder with a wrench. After all of fittings have been started by hand, tighten the retaining bolts and then the brake-line fittings with a line wrench..**
	**DEMONSTRATION:** Show students how to bench bleed a master cylinder.
	**HANDS-ON TASK:** Have students bench bleed a master cylinder with the proper bypass tubing and punch.
 	**ON-VEHICLE ASEEDUCATION TASK A1:** Identify and interpret brake system concerns; determine needed action.
 	**ON-VEHICLE ASEEDUCATION TASK B1:** Diagnose pressure concerns in the brake system using hydraulic principles (Pascal's Law)
 	**ON-VEHICLE ASEEDUCATION TASK B2:** Measure brake pedal height, travel, and free play (as applicable); determine needed action.

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   	**ON-VEHICLE ASEEDUCATION TASK B3:** Check master cylinder for internal/external leaks and proper operation; determine needed action. **ON-VEHICLE ASEEDUCATION TASK B4:** Remove, bench bleed, and reinstall master cylinder.