Instructional Design Writing Samples

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Samples are reproduced from original course materials with institution and company branding removed.
Storyboard is a portfolio sample not associated with any specific client.

eLearning Storyboard

Electrical Circuit Diagnosis & Voltage Drop

Apex Automotive Training Series | D2 Storyboard | Storyline 360 format

Course information

- **Title:** Electrical Circuit Diagnosis & Voltage Drop
- **Audience:** Mid-level technician: A6 candidate or equivalent
- **Prerequisites:** Basic electrical theory; DVOM operation
- **Format:** Storyline 360: self-paced, SCORM 1.2 compliant
- **Est. seat time:** ~25 minutes
- **Slide count:** 20 slides

Interaction legend

- **TITLE:** Course/section title slides
- **SECTION:** Section divider slides
- **CONTENT:** Narrated content: no interaction
- **KNOWLEDGE CHECK:** Single-question formative check
- **DRAG-AND-DROP:** Matching or categorization activity
- **BRANCHING:** Scenario with consequence paths
- **ASSESSMENT:** Scored quiz question

SECTION 1: INTRODUCTION | Slides 1–3

SLIDE 1 | Course Title & Welcome | TITLE	
ON SCREEN	Course title: Electrical Circuit Diagnosis & Voltage Drop Navy background, orange accent Subtitle: A6 Electrical Systems | ~25 min Start button centered bottom Animated circuit line graphic (subtle, background)
VO SCRIPT	Welcome to Electrical Circuit Diagnosis and Voltage Drop. In this course you'll learn how to use your DVOM to perform voltage drop testing on loaded circuits, one of the most powerful diagnostic tools in your kit. By the end you'll be able to find resistance faults that don't show up on a standard voltage test.
DEV NOTES	Storyline: Use entrance animation on title text (fade, 0.5s delay) Start button triggers slide advance Background: subtle animated SVG circuit trace (loop, 30% opacity) Font: Arial Black title, Arial body No audio autoplay: learner initiates with Start button

SLIDE 2 | Learning Objectives | CONTENT	
ON SCREEN	Header: What You Will Be Able to Do Four objectives reveal on click (entrance animation): • 1. Recall Ohm's Law and predict voltage drop in a series circuit • 2. Set up a DVOM correctly for voltage drop testing on a loaded circuit • 3. Identify excessive voltage drop using industry thresholds (0.1V / 0.5V) • 4. Select the correct repair strategy based on voltage drop location Progress bar visible at bottom (Storyline native)
VO SCRIPT	By the end of this course you'll be able to do four things. First, recall Ohm's Law and use it to predict voltage drop in a series circuit. Second, set up your DVOM correctly for a loaded voltage drop test. Third, interpret your readings against industry standard thresholds. And fourth, select the right repair strategy based on where the drop is located.
DEV NOTES	Storyline: Each objective reveals on Next click: use Slide Layers, not Timeline Use numbered icon beside each objective (orange circle, white number) Progress bar: Storyline built-in, themed orange

	No branching: linear reveal only

SLIDE 3 | Why Voltage Drop Matters | CONTENT	
ON SCREEN	Two-column layout: LEFT: Photo placeholder: corroded ground connection on engine block RIGHT: Text content: • Header: The Hidden Resistance Problem • Body: Standard voltage tests check for open circuits. They miss partial resistance, the kind caused by corrosion, loose connections, and damaged conductors. • Callout box: A 0.5V drop across a ground circuit can cause DTC P0030, P0141, erratic O2 data, and multiple misfire DTCs. • Tagline: If you only test for voltage, you'll miss half the faults.
VO SCRIPT	Here's the problem with standard voltage testing. Checking for battery voltage at a component tells you the circuit is not open. It does not tell you if there's excessive resistance in the path. A corroded ground connection might still pass voltage, and still cause symptoms. Voltage drop testing is how we find that hidden resistance.
DEV NOTES	Photo placeholder: use generic engine bay / connector image: no OEM branding Callout box: amber fill, orange left border, italic text Tagline text: large, bold, navy: appears after VO completes (trigger: media complete) No interaction: NEXT button advances

SECTION 2: OHM'S LAW REVIEW | Slides 4–6

SLIDE 4 | Section Title: Ohm's Law | SECTION	
ON SCREEN	Section number: 01 Section title: Ohm's Law & Voltage Drop Fundamentals Orange background, white text Icon: lightning bolt in white circle Estimated time: ~5 minutes
VO SCRIPT	Section one: Ohm's Law and voltage drop fundamentals. Let's make sure we have the foundation before we pick up the meter.
DEV NOTES	Auto-advance after 3 seconds OR learner clicks NEXT Same section divider template used for all section slides Icon sourced from Storyline Content Library or react-icons

SLIDE 5 | Ohm's Law: Interactive Formula | CONTENT	
ON SCREEN	Center: Ohm's Law triangle diagram (interactive) Three segments: V (volts), I (amps), R (ohms) Learner clicks each segment to reveal formula: • V = I × R • I = V / R • R = V / I Below triangle: worked example • A circuit has 12V supply and 2 ohms resistance. • Current = 12 / 2 = 6 amps • Expected voltage drop across 0.5 ohm connector = 6 × 0.5 = 3V Callout: That 3V drop means only 9V reaches the load.
VO SCRIPT	Ohm's Law tells us the relationship between voltage, current, and resistance. Click each section of the triangle to reveal the formula. The key insight for diagnostics: as resistance increases in a series circuit, the voltage drop across that resistance increases, and the voltage available to the load decreases.
DEV NOTES	Storyline: Use Click-to-Reveal state changes on triangle segments Triangle: custom SVG or Storyline shape, segmented into three click targets Each segment: Normal state (navy fill), Hover (orange), Selected (reveals formula text) Worked example appears after all three segments are clicked (trigger: variable = 3) Variable: VarSegmentsClicked (number, default 0) increments on each first click

SLIDE 6 | Knowledge Check: Ohm's Law | KNOWLEDGE CHECK	
ON SCREEN	Question: A circuit has a 12V supply and draws 3 amps of current. What is the total circuit

	resistance? Four answer choices (radio button style): • A. 2 ohms • B. 4 ohms ← CORRECT • C. 36 ohms • D. 0.25 ohms Submit button: reveals feedback layer Correct feedback: green checkmark, 'Correct! R = V/I = 12/3 = 4 ohms.' Incorrect feedback: red X, 'Not quite. Use R = V/I. 12 divided by 3 = 4 ohms. Try again.'
VO SCRIPT	[No VO on question slide: learner reads and responds independently]
DEV NOTES	Storyline: Built-in Pick One quiz slide: SCORM reports this question Attempts: 2 allowed before correct answer is shown Feedback: use Correct/Incorrect slide layers No penalty scoring: formative only NEXT button only appears after Submit on correct answer or second attempt
BRANCHING	Correct → NEXT advances to Slide 7 Incorrect (attempt 2) → Show answer, then NEXT advances to Slide 7

SECTION 3: DVOM SETUP | Slides 7–9

SLIDE 7 | Section Title: DVOM Setup | SECTION	
ON SCREEN	Section number: 02 Section title: DVOM Setup for Voltage Drop Testing Orange background, white text Icon: multimeter graphic Estimated time: ~6 minutes
VO SCRIPT	Section two: setting up your DVOM correctly for voltage drop testing. This is where most techs make their first mistake.
DEV NOTES	Auto-advance 3 seconds or NEXT click Same section template as Slide 4

SLIDE 8 | DVOM Setup: Drag-and-Drop | DRAG-AND-DROP	
ON SCREEN	Instructions: Drag each lead to the correct DVOM terminal for a voltage drop test. Left side: DVOM graphic with three unlabeled terminals (COM, VΩmA, 10A) Right side: Drag items: • Red lead • Black lead • 'Set to DC Volts' label • 'Set to DC Amps' label (distractor) Correct answer: • Red lead → VΩmA terminal • Black lead → COM terminal • 'Set to DC Volts' → Function selector label Drop targets highlight on hover (orange dashed border) Submit button: reveals feedback
VO SCRIPT	Before we test, let's make sure the meter is set up correctly. Drag each item to its correct location on the DVOM. Remember: for a voltage drop test, we measure voltage, not current. The meter goes in parallel with the circuit, not in series.
DEV NOTES	Storyline: Use Freeform Drag-and-Drop question type Drag items: custom rounded rectangle shapes with text Drop targets: DVOM terminal areas (invisible rectangles over DVOM graphic) DVOM graphic: generic multimeter illustration: no branded/OEM meters

	Distractor 'Set to DC Amps' should not have a valid drop target Correct feedback: 'Correct setup! Red to VΩmA, Black to COM, function set to DC Volts.' Incorrect feedback: 'Not quite. For voltage drop, the meter measures voltage: set to DC Volts, leads in VΩmA and COM.' Attempts: 2 allowed
BRANCHING	Correct → NEXT to Slide 9 Incorrect (2 attempts) → Show correct answer overlay → NEXT to Slide 9

SLIDE 9 | DVOM Placement: Loaded Circuit | CONTENT	
ON SCREEN	Animated diagram: simple series circuit (battery → switch → load → ground) Step 1 highlights: circuit energized, load running Step 2 highlights: DVOM probes placed across suspect connector (parallel) Step 3 highlights: reading appears on DVOM screen Callout boxes appear at each step: • Step 1: 'Circuit must be under load: don't test with the load off' • Step 2: 'Probes go ACROSS the component, not in series' • Step 3: 'Reading = voltage consumed by resistance at that point' Three-step progress indicator at top
VO SCRIPT	Voltage drop testing requires the circuit to be operating under load. That's critical: if the load is off, there's no current flow, and there's nothing to drop. Place your red probe on the positive side of the suspect connection and your black probe on the negative side. The reading you get is the voltage being consumed by resistance at that point in the circuit.
DEV NOTES	Storyline: Three-step sequence using Next Slide triggers or Slide Layers Each step: click NEXT to advance animation state Diagram: built in Storyline using shapes: no third-party assets needed Circuit elements: battery (rectangle), switch (line break), load (zigzag resistor symbol), ground (standard symbol) DVOM: simplified rectangle with display area showing reading Animation: use Motion Path or State changes to highlight each element

SECTION 4: THRESHOLDS & INTERPRETATION | Slides 10–13

SLIDE 10 | Section Title: Reading & Interpreting Results | SECTION	
ON SCREEN	Section number: 03 Section title: Reading & Interpreting Voltage Drop Results Orange background, white text Icon: gauge / meter reading graphic Estimated time: ~6 minutes
VO SCRIPT	Section three: reading and interpreting your results. The test is only as good as your ability to make a decision from the number on the screen.
DEV NOTES	Auto-advance 3 seconds or NEXT Same section template

SLIDE 11 | Industry Thresholds | CONTENT	
ON SCREEN	Header: Voltage Drop Thresholds: Industry Standard Three-column comparison card layout: • Column 1 (green): ACCEPTABLE • Power circuits: < 0.1V per connection / < 0.5V total circuit • Ground circuits: < 0.1V per connection / < 0.2V total circuit • Column 2 (amber): MARGINAL • Power: 0.1V–0.3V per connection • Ground: 0.1V–0.2V per connection • Note: May cause intermittent symptoms under load • Column 3 (red): EXCESSIVE • Any reading > 0.5V on power circuit

	• Any reading > 0.2V on ground circuit • Note: Service required Bottom callout: 'When in doubt: refer to OEM service information for model-specific limits.'
VO SCRIPT	The industry standard thresholds give us a baseline for making go/no-go decisions. For a power circuit, anything under 0.1 volts per connection is acceptable. Total circuit drop should be under 0.5 volts. For ground circuits the tolerance is tighter: total drop should be under 0.2 volts. Readings above these thresholds indicate a resistance problem that needs to be found and repaired.
DEV NOTES	Storyline: Three card shapes side by side, colored backgrounds Green card: fill E8F5E9, border 2E7D32 Amber card: fill FFF8E1, border E87722 Red card: fill FFEBEE, border C62828 Cards animate in sequentially (1s delay each): use Timeline Bottom callout: amber fill, appears after all cards visible

SLIDE 12 | Knowledge Check: Threshold Interpretation | KNOWLEDGE CHECK	
ON SCREEN	Scenario setup text: 'You measure a voltage drop of 0.35V across a ground connection on a starting/charging circuit.' Question: Which statement best describes this reading? Answer choices: • A. Acceptable: within the 0.5V total circuit limit • B. Excessive: ground circuits require < 0.2V total ← CORRECT • C. Marginal: no action needed at this time • D. Cannot determine: need more information Feedback correct: 'Right. Ground circuits have a tighter tolerance: 0.2V total is the acceptable limit. 0.35V requires investigation.' Feedback incorrect: 'Not quite. Ground circuits have a lower threshold than power circuits. 0.2V is the acceptable limit for total ground circuit drop.'
VO SCRIPT	[No VO: learner reads and responds]
DEV NOTES	Storyline: Pick One quiz slide: SCORM reported Scenario text styled in italic, navy box above question 2 attempts allowed NEXT only after correct or 2nd attempt
BRANCHING	Correct → NEXT to Slide 13 Incorrect (2 attempts) → Show correct answer → NEXT to Slide 13

SLIDE 13 | Drag-and-Drop: Categorize the Readings | DRAG-AND-DROP	
ON SCREEN	Instructions: Drag each voltage drop reading to the correct category. Three drop zones (columns): ACCEPTABLE | MARGINAL | EXCESSIVE Drag items (six readings): • 0.08V: power circuit connection • 0.18V: ground circuit total • 0.42V: power circuit total • 0.62V: power circuit total [EXCESSIVE] • 0.09V: ground circuit connection [ACCEPTABLE] • 0.15V: power circuit connection [ACCEPTABLE] Correct answers: • ACCEPTABLE: 0.08V (power), 0.09V (ground), 0.15V (power) • MARGINAL: • 0.18V (ground) • EXCESSIVE: 0.42V (power total), 0.62V (power total) Submit → feedback layer
VO SCRIPT	Let's apply the thresholds. Drag each reading to the correct category: Acceptable, Marginal, or Excessive. Pay attention to whether the reading is from a power circuit or a ground circuit. The thresholds are different.
DEV NOTES	Storyline: Freeform Drag-and-Drop Drop zone backgrounds: green / amber / red (low opacity) Drag items: white rounded rectangles, navy text

	Reading labels include circuit type to avoid ambiguity Correct: 5/6 or 6/6 accepted as correct (partial credit option in Storyline) Incorrect feedback identifies which items were miscategorized by name 2 attempts
BRANCHING	All correct / partial → proceed to Slide 14 2nd attempt incorrect → show correct answer overlay → Slide 14

SECTION 5: BRANCHING SCENARIO | Slides 14–17

SLIDE 14 | Section Title: Branching Scenario | SECTION	
ON SCREEN	Section number: 04 Section title: Apply It: Diagnostic Scenario Orange background, white text Icon: branching path / decision tree graphic Intro text: 'A customer complaint is waiting. Use what you've learned to diagnose it.' Estimated time: ~6 minutes
VO SCRIPT	Time to apply everything. You're going to work through a real diagnostic scenario. The decisions you make will affect the outcome, just like in the shop.
DEV NOTES	Auto-advance 3 seconds or NEXT Use branching path icon: suggests consequence-based activity

SLIDE 15 | Scenario: Setup & First Decision | BRANCHING	
ON SCREEN	Scene setup (styled box, navy background): • 2022 pickup, V8. Customer: 'Battery light comes on under load: AC, lights on, radio.' • Scan data: no DTCs. Battery voltage: 12.6V key off. 13.8V at idle: normal. • Symptom: voltage drops to 12.1V under full electrical load. Question: What is your first diagnostic step? Three choices (button style): • A. Replace the alternator: voltage is low under load • B. Perform a voltage drop test on the charging circuit ← CORRECT PATH • C. Load test the battery: suspect weak battery
VO SCRIPT	The battery light is coming on under electrical load, but your scan shows no DTCs and voltage looks normal at idle. What do you do first?
DEV NOTES	Storyline: Use button branching: each button has Jump to Slide trigger Scene setup: navy rounded rectangle, white text, italic scenario text Buttons: rounded rectangles, navy border, white fill, navy text Hover state: orange fill, white text No submit button: button click immediately navigates Track attempt in variable: VarScenAttempt (number)
BRANCHING	Choice A → Slide 15A (Incorrect Path: alternator replacement without testing) Choice B → Slide 16 (Correct Path: voltage drop test) Choice C → Slide 15B (Partially correct: useful test but not first step)

SLIDE 15A | Incorrect Path: Parts Cannon | BRANCHING	
ON SCREEN	Header (red background): Not the Best Move Body: Replacing the alternator without testing assumes the alternator is the fault. But voltage drop in the charging circuit would cause identical symptoms, and alternators are expensive. Consequence: You replace the alternator. The battery light returns the next day. Callout: Always test before replacing. A voltage drop test would have taken 5 minutes. Button: Try Again → returns to Slide 15 Button: See the correct approach → jumps to Slide 16
VO SCRIPT	Replacing the alternator without testing is a common mistake. The symptoms are consistent with a failing alternator, but they're equally consistent with excessive resistance in the charging circuit. A voltage drop test costs nothing but time. Parts replacement costs the customer money.
DEV NOTES	Storyline: Consequence layer: red header shape, body text, two button options Increment variable VarScenAttempt on entry to this slide

	Try Again: Jump to Slide 15 (VarScenAttempt resets if desired, or tracks for reporting) Track incorrect path visits in variable for reporting
BRANCHING	Try Again → Slide 15 See correct approach → Slide 16 (bypasses second attempt)

SLIDE 15B | Partial Credit Path: Battery Test | BRANCHING	
ON SCREEN	Header (amber background): Close, But Not First Body: A battery load test is a valid diagnostic step, but it's not first in this sequence. The battery voltage at idle is 13.8V, indicating the alternator is charging. The symptom is voltage drop under load, which points to resistance in the charging circuit. Callout: The battery is likely fine. Start with a voltage drop test on the charging circuit. Button: Go back and reconsider → Slide 15 Button: Continue to the correct first step → Slide 16
VO SCRIPT	A battery load test is a useful tool, but in this scenario, you already know the alternator is charging at idle. The question is whether the charging voltage is reaching the battery efficiently under load. That's a voltage drop question, not a battery capacity question.
DEV NOTES	Storyline: Amber consequence layer: styled differently from incorrect path Two button options: learner can self-correct or continue This path should be tracked but not penalized in scoring
BRANCHING	Go back → Slide 15 Continue → Slide 16

SLIDE 16 | Correct Path: Performing the Test | BRANCHING	
ON SCREEN	Header (green background): Good Thinking Body: You set up your DVOM and perform voltage drop tests on the charging circuit. Animated diagram: charging circuit (alternator → fusible link → battery positive → load) Test results appear sequentially (click to advance): • Alternator output stud to fusible link: 0.08V ✓ Acceptable • Fusible link to battery positive: 0.09V ✓ Acceptable • Battery positive terminal to cable end: 0.68V × EXCESSIVE Callout: Found it. The battery positive cable connection is corroded. Question: What do you do next? Two choices: • A. Clean and tighten the battery terminal connection ← CORRECT • B. Replace the battery and cable assembly
VO SCRIPT	Good call. You perform voltage drop tests at each point in the charging circuit. The first two points look fine: but the battery positive cable connection shows 0.68 volts of drop. That's way above the 0.1V threshold for a single connection. You've found the fault. Now what?
DEV NOTES	Storyline: Green consequence header, then animated test result sequence Each test result: click NEXT to reveal next measurement Results: styled as DVOM screen graphic with reading displayed Third result (0.68V): red text, warning icon, 'EXCESSIVE' label Question and buttons appear after all three results revealed
BRANCHING	Choice A → Slide 17 (Correct resolution) Choice B → Slide 16B (Over-repair path)

SLIDE 17 | Scenario Resolution | BRANCHING	
ON SCREEN	Header (navy background, orange accent): Diagnosis Complete Summary layout: • Fault: Corroded battery positive cable connection: 0.68V drop • Service: Clean and tighten terminal: verify drop returns to < 0.1V • Verify: Retest under full electrical load: battery light gone • Result: Customer confirmed satisfied. No return visit. Key takeaway box (orange border): • 'A 5-minute voltage drop test identified a fault that looked like alternator failure. • Test before you replace.'

	NEXT → Slide 18 (Assessment intro)
VO SCRIPT	Clean the terminal, tighten it, and retest. The voltage drop returns to 0.07 volts, well within spec. Road test under full electrical load, and the battery light stays off. The customer drives away happy, and you didn't replace an alternator that didn't need it.
DEV NOTES	Storyline: Navy header with orange accent bar (shape) Summary: three-row table: Fault / Service / Verify / Result Key takeaway: styled callout box: prominent, last element on slide NEXT button → advances to Slide 18

SECTION 6: ASSESSMENT | Slides 18–20

SLIDE 18 | Assessment Introduction | SECTION	
ON SCREEN	Section number: 05 Section title: Knowledge Check: 5 Questions Orange background, white text Body: 'Answer all five questions. You need 80% (4/5) to pass. You have two attempts per question.' Icon: checkmark / assessment graphic Begin Assessment button
VO SCRIPT	You've completed the course content. Now let's see what you know. Five questions: you need four out of five to pass. Take your time.
DEV NOTES	Begin Assessment button → Slide 19 Results slide at Slide 20: Storyline native results slide SCORM reports quiz score

SLIDE 19 | Assessment: Questions 1–5 | ASSESSMENT	
ON SCREEN	QUESTION 1 (Pick One): • A circuit has a 12V supply and 4 amps of current flow. What is the total resistance? • A. 48 ohms B. 3 ohms C. 0.33 ohms D. 8 ohms ← CORRECT: B (3 ohms) QUESTION 2 (Pick One): • For a voltage drop test, how must the DVOM be connected to the circuit? • A. In series with the load B. In parallel across the suspect connection ← CORRECT • C. Across the battery terminals D. In series with the battery QUESTION 3 (Pick One): • You measure 0.38V across a single ground connection. What is the correct interpretation? • A. Acceptable: under 0.5V total limit • B. Marginal: monitor but no action needed • C. Excessive: ground circuits must be under 0.2V ← CORRECT • D. Cannot determine without full circuit test QUESTION 4 (Pick One): • A circuit must be _____ when performing a voltage drop test. • A. De-energized B. Under load with current flowing ← CORRECT • C. Disconnected from the battery D. Set to key-on engine-off QUESTION 5 (Pick One): • A technician finds 0.08V across each of three connections in a power circuit. What is the total circuit drop? • A. 0.08V B. 0.24V ← CORRECT C. 0.50V D. Cannot calculate without resistance
VO SCRIPT	[No VO on assessment slides: learner reads and responds]
DEV NOTES	Storyline: Use Question Bank or sequential quiz slides Each question on its own layer or slide: use Storyline quiz engine 2 attempts per question: Storyline native setting Results reported to SCORM: score, pass/fail, time on task Pass threshold: 80% (4/5 correct) No feedback on individual questions: only summary on Results slide Randomize question order if desired (Question Bank feature)
BRANCHING	All 5 complete → Slide 20 (Results)

	Pass (≥ 80%) → Certificate of completion message Fail (< 80%) → Option to review course content or retake assessment

SLIDE 20 | Results & Course Close | ASSESSMENT	
ON SCREEN	Storyline native Results Slide: customized: PASS state: • Large checkmark (green), 'Course Complete' • Score display: X / 5 correct • Message: 'Excellent work. You've demonstrated solid understanding of voltage drop testing.' • Buttons: Review Course | Exit FAIL state: • Score display: X / 5 correct • Message: 'Not quite. You need 4 out of 5 to pass. Review the content and try again.' • Buttons: Review Course | Retake Assessment Bottom: navy bar, orange accent, sample disclaimer
VO SCRIPT	[Results slide: no VO]
DEV NOTES	Storyline: Native Results slide, customized with the course theme Use Results slide variable %Results.ScorePercent% for display Pass/Fail states: use built-in Storyline conditions Review Course: jumps to Slide 1 (resets completion tracking per SCORM settings) Retake Assessment: jumps to Slide 18 (resets quiz variables) Exit: triggers LMS exit via JavaScript or Storyline Exit Course trigger SCORM: report cmi.core.lesson_status as 'passed' or 'failed'
BRANCHING	Pass → Exit LMS or Review Course Fail → Retake Assessment (Slide 18) or Review Course (Slide 1)

Sample storyboard. Not associated with any specific client. For portfolio use only.

FACILITATOR GUIDE

Hydraulic Power Steering Systems

Topic	**Steering and Suspension (postsecondary automotive technology)**
Session	**Single lecture session**
Designed by	**Will Wallace**
Service Info Reference	**OEM service information**

How to Use This Guide

This guide is keyed to slide numbers in the lecture deck. Each slide row lists talking points, lab/demo cues, and check triggers. Read the row while the slide is live. Not before. Notes are written in instructor voice, not learner voice. Scope note: this deck and guide are hydraulic power steering only. EPS and steer-by-wire live in their own module and deck; don't pull that material in here even if a learner asks a leading question.

Session Learning Objectives (Mager Format)

State the terminal objective aloud at Slide 2, then let learners know the enabling objectives are what each section builds toward. Full objectives are wordy for a slide. The deck shows short summaries; this is the assessment-grade version.

- Terminal Objective: Given a customer-reported steering complaint on a vehicle equipped with hydraulic power steering, the learner will correctly diagnose the fault to one of five categories (pump, control/flow-control valve, hose, steering gear/rack, or fluid) and recommend the correct corrective service, achieving 100% accuracy across the diagnostic case scenarios in the module assessment.
- EO1: Given a labeled two-chamber hydraulic force-transmission diagram, the learner will state Pascal's Law and calculate the resulting output force or pressure, with at least 4 of 5 problems answered correctly.
- EO2: Given a cutaway illustration of a vane-type power steering pump, the learner will identify the rotor, vanes, cam ring, thrust plate, and pressure plate, and sequence the six phases of vane pump operation in the correct order, with 100% accuracy.
- EO3: Given a described symptom (e.g., chatter at full lock, pressure spike), the learner will explain the function of the flow control (modulator) valve and pressure-relief valve, correctly identifying low-speed, high-speed, and relief-mode operation in at least 3 of 4 scenario questions.
- EO4: Given cutaway diagrams of an integral (recirculating-ball) gear and a rack-and-pinion gear, the learner will identify the rotary control valve position (neutral, left-turn, right-turn) and predict fluid flow direction, with at least 4 of 5 diagram items correct.
- EO5: Given descriptions of GM's EVO, TFE, SSS, and Magnasteer® variable-effort steering systems, the learner will match each system to its actuator type and speed-based assist behavior, with 100% accuracy on the matching exercise.
- EO6: Given a described customer complaint (noise, jerky steering, hard steering, loss of assist) and a symptom checklist, the learner will identify the most probable root cause(s) and the

correct first diagnostic step, achieving at least 80% accuracy on the case-based diagnostic worksheet.

- EO7: Given a vehicle requiring power steering fluid service, the learner will correctly perform the fluid flush and air-bleed procedure, verified by a fluid-rise check of less than 0.020 in. (0.5 mm), and correctly sequence a rack-and-pinion R&R with zero missed critical safety steps (clock-spring lockout, never running the reservoir dry), as scored on the lab rubric.

Timing Plan. 36 Slides · Estimated Delivery: 100–110 min (includes discussion, not just read-through)

Slides	Time Block	Topic	Suggested Clock
1–2	5 min	Cover · Session Objectives	6:00–6:05
3–5	10 min	Hydraulic Fundamentals · Pascal's Law · CFU 1	6:05–6:15
6–11	18 min	Pump & Reservoir · Pressures · Vane Pump · CFU 2 · Control Valve · EHPS	6:15–6:33
12–14	8 min	Flow Control Valve Operation · Hoses · Fire Safety	6:33–6:41
15–17	10 min	Integral Gear · Rotary Valve · Rack-and-Pinion Operation & Durability	6:41–6:51
18–19	10 min	Rack R&R: Removal & Installation (lab tie-in)	6:51–7:01
20–23	12 min	VES: EVO · TFE/SSS · Magnasteer® · CFU 3	7:01–7:13
24–26	10 min	Diagnosis Checklist (1 of 2, 2 of 2) · Electronic-Modulated Assist	7:13–7:23
27–29	10 min	Fluid Selection · Flushing · Bleeding	7:23–7:33
30–32	10 min	Pressure Testing · Specs · Case Study Discussion	7:33–7:43
33–36	8 min	Pump Service · Pulley/Seal Service · Summary	7:43–7:51

Pre-Flight Checklist

- Have a power steering pressure tester and a flow-control valve (pulled from a scrap pump if available) staged for hands-on pass-around at Slides 9 and 33–34.
- Stage a rack-and-pinion unit (scrap or lab vehicle) for the R&R walkthrough at Slides 18–19. Ideally with the boot/bellows visible so you can point at the failure points from Slide 17 live.
- Confirm service information access for a live pull of vehicle-specific PS fluid spec and belt tension spec. Reinforces "always check service info, don't guess" (Slide 27).
- If a shop vehicle with a cold-start power steering noise is available, mention it before the case study (Slide 32). Real, current example beats a textbook case study every time.
- Whiteboard marker at the ready for Slide 3 (Pascal's Law) if you want to sketch the two-chamber force diagram live instead of relying solely on the recommended slide image.

Slide-by-Slide Delivery Notes

Slide #	Title / Topic	Instructor Notes & Talking Points	Check / Cue
1	Cover: Hydraulic Power Steering	• Give learners 60–90 seconds to settle and find their notes.	No action. Transition to

		• State the scope boundary up front: "This module is hydraulic power steering only. Pump, valves, gears, diagnosis, and service. EPS and steer-by-wire get their own session." This heads off confusion later.	objectives.
2	Session Objectives	• Read the short on-slide objectives aloud, but don't over-explain. You'll build to each one. • Mention that the full Mager-format objectives (with criteria) are in this guide and the study guide if anyone wants the exact assessment language.	Ask: "Which of these do you already feel solid on from shop experience?" Gauge the room.
3	What Hydraulic Power Steering Does	• Ground this in shop reality immediately: every learner has driven or worked on a vehicle with dead power steering. Ask what that felt like. • Force vs. pressure distinction matters later when you get to the pressure/volume spec chart (Slide 31). Plant the seed now.	Cold call: "Describe steering effort with the power steering belt off."
4	Pascal's Law	• The incompressibility point is the one learners forget fastest. Emphasize that a liquid transmits force like a solid lever, but through any-shaped path. • If you sketch the two-chamber diagram on the board, use it to preview why a bigger piston area at the output = force multiplication (ties directly into the rack piston later).	**Use a board sketch or the recommended diagram.**
5	CFU 1: Purpose of a Power Steering System	Quick, low-stakes. This is a warm-up check, not a graded moment.	Cold call 2–3 learners before revealing the key points.
6	Power Steering Pump & Reservoir	• Integral vs. remote reservoir. If you have a scrap pump, this is the moment to pass it around. • Note the horsepower figures (½ hp straight, ~3 hp parking). Useful for explaining why idle can sag during a slow parking-lot turn on a tired engine.	Pass around scrap pump if staged.
7	Power Steering Pressures by Steering Action	• Frame this as "the numbers you'll see on a pressure tester". Sets up Slide 30 directly. • The chatter/squeal-at-full-lock note is a great "have you heard this noise" moment. Most learners have.	Ask: "Who's heard that groan/squeal when someone holds the wheel at full lock? What's actually happening?"
8	Vane Pump Operation	• Walk the six phases in order, pointing at the recommended cutaway image (or a scrap pump rotor if you have one disassembled). • Don't get lost in phase-by-phase memorization. The test-relevant takeaway is centrifugal force + ring contour = draw-in then discharge.	**Safety/pass-around note: rotor/vane assembly has sharp edges. Caution if passing around a disassembled unit.**
9	CFU 2: How does a vane-type	Listen for "centrifugal force pushes vanes out" and "ring	Cold call. If nobody

	pump operate?	shape changes cavity volume". Those are the two load-bearing ideas.	gets both ideas, do a 60-second re-explain before moving on.
10	Control (Modulator) Valve	• This is the part learners find hardest to visualize. Lean on the recommended cutaway diagram. • Key phrase: "this is a pressure regulator, not a shutoff valve". It bleeds excess, it doesn't fully stop flow under normal operation.	No special cue. Pacing slide.
11	Current Shop Reality: EHPS on Heavy-Duty Trucks	• This is the one piece of "currency" content added beyond the two textbooks. Flag it as such: "this isn't in either of your books, it's current industry context." • Tie it to any learners with diesel/heavy-truck aspirations. Good moment to ask who's interested in that track.	Ask: "Any of you already seen an electric-pump hydraulic steering system in the shop or on a truck you've worked?"
12	Flow Control Valve Operation: Low/High/Relief	• This is the densest single slide in the deck. Slow down here. Use the low-speed → high-speed → relief-mode sequence as a story, not a list. • Relief mode is the direct cause of the noise from Slide 7. Call that connection out explicitly.	No special cue. Allow extra time, this is the hardest concept slide.
13	Power Steering Hoses	• Pressure vs. return hose distinction sets up a common ASE-style test question (which hose has the clamp). • 300°F / 1,500 PSI spec is worth writing on the board. Learners remember numbers they wrote down.	No special cue.
14	Hose Inspection & Fire Safety	• Safety-critical slide. The fire hazard point (fluid flammable just above 300°F, lower than manifold temp) is not obvious and worth repeating twice. • Spongy hose = replace, no judgment call. Make that a bright line, not a gray area.	**SAFETY CALL-OUT: state explicitly that a failed pressure hose spraying onto an exhaust manifold is a fire risk, not just a leak.**
15	Integral Power Steering (Recirculating-Ball Gear)	• Most learners will have seen a rack-and-pinion system far more than a recirculating-ball gear. If you have an older truck/SUV steering box on hand, this is the moment. • Ball nut = power piston is the one-sentence takeaway.	No special cue.
16	Rotary Control Valve Operation	• Neutral / left-turn / right-turn / release. Walk it exactly like the vane pump phases, as a repeating cycle. • Torsion bar stiffness = steering feel is a good "why do sports cars feel different" hook.	Ask: "Why would a performance car use a thicker torsion bar here?"
17	Power Rack-and-Pinion Steering	• Contrast directly against Slide 16. Same rotary valve concept, different housing (rack vs. gear box).	No special cue.

		• This is the system the vast majority of your learners will actually service. Spend real time here.	
18	Rack-and-Pinion Durability & Failure Points	• The weight-reduction-vs-durability trend (54 lb down to 8–10 lb) is a good "why modern parts fail differently than old parts" discussion. • Grayish/thick fluid + cold-start assist loss is a diagnostic signature worth having learners write down verbatim. It shows up on unit-test-style questions.	Ask: "If a customer says the steering feels normal once warmed up but stiff on a cold start, what does that tell you?"
19	Rack-and-Pinion Removal: Key Steps	• This is the lab tie-in slide. If a rack is staged, walk to it now and point at each item as you describe it. • **Non-negotiable safety point: lock the wheel / pull the key before disconnecting anything. State this before showing the image, not after.** • The full 18-step photo sequence and coupler detail live in the lab handout. This slide is the headline version.	• **SAFETY CALL-OUT: clock spring lockout. Do not skip.** • Transition to lab if this is a lab day.
20	Rack-and-Pinion Installation & Air Bleed	• Bump steer callout is a good "why torque sequence and bracket orientation matter" moment. Not just "torque it to spec because I said so." • Reinforce: bleed with wheels off the ground, engine off, cycle lock-to-lock.	No special cue.
21	VES: Overview & EVO	• Frame VES as "the industry's answer to one universal complaint: parking lot steering is too heavy, highway steering is too light and vague." • EVO's steering-wheel speed sensor (evasive maneuver detection) is the most interesting/memorable detail. Spend a beat there.	No special cue.
22	VES: TFE & SSS	• TFE is the simplest system in the whole module (2-state pintle). Good confidence-builder slide after the denser EVO explanation. • SSS is the outlier: it resists movement rather than assisting it. Make sure that distinction lands, it's a common mix-up point.	Ask: "Which of these two systems works backwards compared to the others we've covered? Why?"
23	VES: Magnasteer®	• The polarity-reversal-at-45mph detail is genuinely interesting to most learners. It's a real "electricity doing mechanical work" example. • Keep the amperage numbers (1.6A stationary, reversing at 45mph) on the board if you're taking notes live.	No special cue.
24	CFU 3: Purpose of Variable-Effort Steering	This is the natural end-of-VES-section checkpoint before moving into diagnosis.	Cold call 2–3 learners.

25	Power Steering Diagnosis: Common Causes (1 of 2)	• This is a "continued" slide pair by design. 8 total checklist items split across two slides to stay under the 6-bullet limit. Treat both as one continuous list when teaching. • Belt tension is the single most common, cheapest thing to check first. Say this explicitly, it's testable.	No special cue.
26	Power Steering Diagnosis: Common Causes (2 of 2)	The turning-effort spring-scale spec (< 5 lb / 2.3 kg) is a good hands-on-lab callback if you have a scale in the shop.	Ask: "Which of these 8 causes would you check first, and in what order? Why?"
27	Diagnosing Electronically-Modulated Hydraulic Assist	Reinforce the scope boundary again here: this is hydraulically-assisted steering with electronic modulation (VES), NOT full EPS. The diagnostic sequence (visual → scan tool → DTC → chart) is still hydraulic-system-adjacent, unlike full EPS module diagnostics which live in the other module.	No special cue.
28	Power Steering Fluid: Selection & Routine Checks	• **Left-hand thread caution is easy to forget and easy to strip a cap over. Call it out by name.** • The Visual Test (finger in the reservoir) is a great low-tech diagnostic learners can do on day one in the shop.	**SAFETY/CAUTION CALL-OUT: left-hand-thread reservoir caps on some vehicles.**
29	Power Steering Fluid Flushing Procedure	• **Never let the reservoir run dry. Say this before walking the steps, not after.** • Two-person job. Good moment to talk about lab partner coordination for the upcoming lab.	**SAFETY CALL-OUT: reservoir must never run dry during flushing.**
30	Bleeding Air Out of the System	• The fluid-rise test (<0.020 in. / 0.5 mm) is a precise, testable number. Write it on the board. • Hydro-boost brake note is a good "wait, brakes use power steering fluid?" surprise moment for learners who haven't hit that vehicle type yet.	No special cue.
31	Pressure Testing the System	• Walk this as a step-by-step lab procedure preview, not just theory. If you're doing a pressure-test lab later in the course, reference it directly here. • The "unequal pressure at both stops = internal leak" diagnostic conclusion is a strong test question candidate.	No special cue.
32	Pressure & Volume Specifications	This is a reference-table slide. Don't over-teach it, just make sure learners know it exists and where to find it (also in the study guide).	No special cue. Quick pace.
33	Case Study Discussion: Dodge Grand Caravan	• Let learners guess before revealing the key points. The "first shop quoted a full pump" detail makes the twist land harder. • Good moment to underline: cheap-fix-first diagnostic discipline saves customers real money and builds trust.	Ask the class before revealing: "What would you check first, and why?" Give it 60 seconds of discussion.

34	Pump Service: What Can Be Done Without Removal	If a scrap pump/flow control valve is staged, this is the moment to physically show the crocus-cloth polishing step.	No special cue.
35	Pulley, Seal & Flow Control Valve Service	• **Never hammer the pump shaft/pulley. Call this out explicitly, it's the most common way learners damage a lab unit.** • Pump ring orientation (upside down = zero output) is a great "small mistake, total failure" example.	**CAUTION CALL-OUT: never hammer the shaft or pulley during install.**
36	Session Summary	• Close by restating the scope boundary one final time: "Next session is Electric Power Steering and steer-by-wire. A genuinely different diagnostic world from what we covered today." • If a lab follows, transition directly; if not, preview the next session's format.	Transition to lab, or dismiss with next-session preview.

Facilitator Guide: Automotive Wiring and Wire Repair

Designed by Will Wallace

The Night at a Glance

Tonight's session is Automotive Wiring and Wire Repair. You lecture from 4:00 to about 6:00, then learners go straight into a wire repair lab. Thursday finishes sign-offs and debriefs. This guide walks the deck in order and tells you what to say, what learners get wrong, and where the textbook and online homework disagree with your slides.

The deck is version 4 of the wiring lecture deck. It has 67 visible slides and two hidden backup slides. Every section ends with a Check for Understanding slide, and the answers live in the speaker notes.

The one objective that drives the night. By the end of lab, each learner selects the correct wire gauge and fuse for a circuit, then completes a weatherproof wire repair. They are given a vehicle or training board, service information, a wire gauge chart, a test light, and the standard repair tools. The repair passes when it survives a tug test, is sealed at both ends with no bare copper showing, matches or beats the original wire gauge, and the circuit works with the correctly rated fuse installed. Say those four checks out loud early and often. They are the lab sign-off.

The time plan. Lecture runs about 108 minutes plus a 10-minute break.

- 4:00: hook and objective, 5 minutes
- 4:05: Section 1, wire and wire gauge, 14 minutes
- 4:19: Section 2, grounds, battery cables, and jumper cables, 10 minutes
- 4:29: Section 3, fuses, 19 minutes
- 4:48: break, 10 minutes
- 4:58: Section 4, other circuit protection devices, 15 minutes
- 5:13: Section 5, terminals and connectors, 8 minutes
- 5:21: Section 6, wire repair, 22 minutes
- 5:43: Section 7, electrical conduit, 4 minutes
- 5:47: whole-task rehearsal, 8 minutes
- 5:55: wrap-up, 3 minutes, and lab starts around 6:00

If you fall behind, four slides drop to 30-second talk-overs: Gauge by Job, Why 6 Volt Cables Are Bigger, Know Your Fuses, and the metric wire chart. Sections 3 and 6 are the heavy ones and feed the lab directly, so protect their time.

Videos. Only one plays live: the publisher video on testing a fuse with a meter, on the fuse testing slide. Check its run time before class. The Electrical Wire Repair video plays at the splice bench during lab. The three Check Your Understanding videos are assigned as online homework.

The Opening: A Window That Has Voltage

Open with a story and don't give the answer away. A customer's driver window crawls up and sometimes stops halfway. The tech pulls the door panel, unplugs the window motor, and puts a digital multimeter on the harness connector. With the switch held up, the meter reads 12.5 volts. Power is there, so the motor must be bad. A new motor goes in, and the window still crawls.

Ask the room what the meter missed. Take every guess and confirm none of them. Tell them to hold the thought until Section 4.

Here is the answer, for you only. The circuit is protected by a positive temperature coefficient device, called a PTC. It has tripped into very high resistance. A multimeter draws almost no current, so it reads nearly full voltage straight through a tripped PTC. Put a real load on the circuit, like the motor or a test light, and the voltage collapses. The new motor still crawled because a binding window track kept tripping the PTC.

This ties straight back to the circuit testing module. An open-circuit voltage reading tells you nothing about whether a circuit can carry current. That is why we load-test and voltage-drop test.

The objective slide comes second. Read it in plain language: pick the right wire, pick the right fuse, and make a repair that survives a pull and the weather. Then name the four sign-off checks so learners build toward them all night. Safety content, like the orange high-voltage conduit, is discussed but not tested.

Section 1: Wire and Wire Gauge

The core idea: wire gauge numbers run backward, metric sizes run forward, and longer runs need bigger wire. Pass around stripped wire samples while you talk.

Why copper. Most automotive wire is stranded copper with plastic insulation. Copper conducts well, costs reasonably, and the fine strands flex. Solid wire work-hardens and cracks under vibration, and a car is nothing but vibration.

The backward system. American Wire Gauge, or AWG, is the U.S. sizing system. A bigger number means a smaller wire, so 14 gauge is smaller than 10 gauge. More current needs a larger conductor, which means a smaller gauge number. A memory hook: the gauge number is roughly how many times the wire was drawn through a die. More draws, thinner wire. Gauge measures the metal conductor only; insulation does not count. Plant that last point hard, because it comes back with cheap jumper cables.

Gauge by job. Speaker wire is 20 to 22 gauge. Small bulbs are 18, taillights and wipers 16, and horns, headlights, and brake lights 14. Defoggers and power windows are 12, and the alternator-to-battery wire is 10. Battery cables are 4, 2, or 1/0. Ask learners where they've seen each size. Service information is always the final word.

Metric wire. Most wiring diagrams print size in square millimeters of conductor cross-section. Metric runs forward: bigger number, bigger wire. A wire marked 0.8 on a diagram is about 18 gauge, and 2.0 is about 14. If the number is a decimal under one, it is almost certainly metric, not gauge.

Length matters. Every wire has resistance, and longer wire has more of it. That resistance sits in series with the load and steals voltage from the bulb or motor. Long runs need a bigger wire. When mechanical strength matters, as in door jambs or trailer plugs, go up one size.

Reading the wire sizing chart. Find the amps row, then the length column. If the run falls between columns, always round the length up. Rounding down undersizes the wire. The highlighted example: a 15 amp trailer circuit needs 14 gauge at 15 to 20 feet, and 12 gauge past 20 feet.

One safety caveat for you: The wire sizing chart sizes wire for voltage drop only. The wire also has to carry the fuse rating. If the fuse you'd pick is more than the wire can safely carry, step the wire up a size.

Practice answers.

1. A 20 amp load on a 10 foot run is 16 gauge for voltage drop. Fused by the 80/20 rule it would get a 25 amp fuse, more than 16 gauge should carry, so in a real repair you'd step up to 14 or follow the spec.
2. A 7 amp load on a 25 foot run is 16 gauge.
3. A 10 amp load on an 18 foot run rounds up to the 20 foot column, which is 16 gauge.
4. A diagram marked 0.8 is 18 gauge.
5. A 14 gauge wire cannot be repaired with 16 gauge. A repair matches or beats the original, and 16 is smaller.

Check for Understanding answers. 10 gauge is larger than 14. A diagram calling for 2.0 square millimeters is 14 gauge. Thick insulation does not make a heavier gauge. Same current on a longer run needs a bigger wire, because more length means more resistance and more voltage drop. If anyone misses the insulation question, flag it now; it returns in Section 2.

Section 2: Grounds, Battery Cables, and Jumper Cables

The core idea: grounds complete the circuit, and a cable's gauge is its copper, never its jacket.

Two kinds of ground. Every vehicle runs ground wires engine-to-body, body-to-battery negative, or both. They come as insulated copper wire or as braided ground straps. Braided straps are uninsulated, because touching metal is the point. They also flex better, which matters because the engine moves on its mounts. Your field story: a broken engine ground sends starter current hunting through throttle cables, shift cables, or cooler lines. A melted throttle cable means a missing engine ground.

Follow the return path. Lights and accessories ground to the body. The body ground wire carries that current back to the engine, and most battery negative cables attach to the engine. The path runs load, body, body ground wire, engine, battery negative. A bad link anywhere in that chain looks like a bad load. Tie it to ground-side voltage drop testing from the circuit testing module: anything over about 0.1 to 0.2 volts on a low-current ground is worth chasing.

The exhaust strap. Exhaust gas flow builds static. Rubber hangers and gaskets isolate the exhaust from ground, so without a strap the static arcs to the body or frame. Those arc points rust out early. Reconnect the strap at both ends on every exhaust job, and check the fuel filler tube strap too. A missing strap after a muffler job is a classic comeback.

Skin effect. You decided to teach this as the book states it, to match the online quiz wording. High-frequency alternating current travels along the outer skin of a conductor, while direct current uses the whole conductor. More, finer strands mean more surface area and less AC resistance. The book says braided straps damp radio interference this way, and that’s why speaker cable uses fine strands. Keep it to about a minute. The shop takeaway: replace a braided strap with a braided strap, not round wire.

Battery cables and ought sizes. Battery cables are the biggest wires in the car, 4 gauge and larger. Cables larger than 1 gauge are called ought: 1/0 is one ought, 2/0 is two ought, 3/0 is three ought. More zeros means a bigger cable. If a learner removes a battery thermal blanket during service, it goes back on.

Why 6 volt cables are bigger. Put Watt’s law on the board: current equals power divided by voltage. An 1,800 watt starter draws 150 amps at 12 volts and 300 amps at 6 volts. Half the voltage, double the current, so 6 volt systems need cables two sizes larger. Learners will meet this on antique cars and older tractors.

Jumper cables. Teach 4 gauge minimum, up to 2/0, with heavy clamps. The book says 6 gauge in one spot; 4 gauge is the standard in this course. Avoid aluminum, which conducts less well and cracks with repeated bending. 1/0 welding cable with welding clamps makes an excellent set because its very fine strands stay flexible. Many cheap cables are copper-clad aluminum: look for silver metal under a thin copper skin at the cut end.

Don’t trust the jacket. Many low-cost jumper cables hide small wire in thick insulation. They look heavy and drop voltage when it counts. The cut-cable demo moves to a side table at the splice bench to protect your clock, so describe it here.

Check for Understanding answers. The taillight return path is bulb, body, body ground wire, engine, battery negative cable. Odd exhaust rust after a muffler job means a missing ground strap. A 6 volt system needs bigger cables because half the voltage means double

the current. To pick between two jumper sets with the same jacket, check the conductor gauge, choose copper over aluminum, and insist on 4 gauge minimum.

Section 3: Fuses

The core idea: a fuse protects the wire, not the component. Test both sides, and read the number, not the color.

Why we fuse. Every circuit should be fused. The fuse keeps the wiring from overheating during a short. It won't save a shorted motor, but it keeps the wire feeding that motor from becoming a heating element and starting a fire. Fuses, and every protection device in this module, are installed in series. On a schematic the fuse symbol is a wavy line between two points, and it shows up again next week in wiring schematics.

Inside a fuse. A fine metal conductor sits inside a glass, plastic, or ceramic housing. Too much current melts it and opens the circuit. One fuse often feeds several circuits; the accessory socket fuse may also run the courtesy lights and clock. Diagnostic angle: when two things quit at once, think shared fuse before you think two failures.

The underhood electrical center. This is the main underhood fuse and relay box, also called a smart junction box. Its circuits are interconnected underneath, not just plugged into the top. After collision or water damage, the usual call is to replace the whole assembly, because hidden bus bars and traces may be corroded or cracked.

The 80/20 rule. Fuse rating runs about 20 percent above normal current, so normal current is about 80 percent of the rating. The quick math is normal current divided by 0.8, then the next standard size up. 12 amps divided by 0.8 is 15 amps. Then say the rule that matters more: in the shop, the manufacturer's rating wins. The wire must be able to carry the fuse. Never up-size a fuse that keeps blowing; that moves the weak link from the fuse to the wire.

Know your fuses. Standard blade fuses have been around since 1977, sold under names like ATO and ATC, with test openings on top. Mini fuses save space so each circuit gets its own fuse, which makes diagnosis easier. Maxi fuses are big plug-in blades up to about 80 amps and replace fusible links on many vehicles. Pacific fuse elements arrived in the late 1980s for direct shorts and have a clear top for inspection. Micro 3 and low-profile minis are newer space savers.

Color codes. The slide shows the colors that hold across makers from 5 to 30 amps: tan 5, brown 7.5, red 10, blue 15, yellow 20, white or clear 25, green 30. Then the maxi chart, where the colors repeat with different ratings. Red is 10 amps on a blade and 50 on a maxi. Blue is 15 versus 60. Brown is 7.5 versus 70. That is the teaching moment: a tech who goes by color alone will eventually install the wrong fuse.

Name-brand fuses only. This is a red, discussion-only safety slide. Some off-brand fuses don't blow until current is far past their rating, so the wire overheats instead. Ask if anyone has seen foil, a bolt, or a wire in a fuse slot. Someone always has, and that is how cars burn.

Test, don’t look. A fuse that looks fine can still be open from a bad internal connection or a bad holder. With the circuit powered, put a test light on both test points. Lit on both sides means the fuse is good. Lit on one side means the fuse is open. Lit on neither side means no power is reaching the fuse, so check the key or switch position, then the feed upstream. Repeat the habit from the circuit testing module: check the test light on battery positive first, or a bad ground clip will make every fuse look open. Play the Test, Meter video here, then a quick live demo on a fuse panel.

Check for Understanding answers. An 8 amp normal load gets a 10 amp fuse. A red blade and a red maxi are not the same; one is 10 amps and the other 50. Lit on one side only is an open fuse. Lit on neither side means no power to the fuse; check the switch position, then the feed.

Take the break after this check.

Section 4: Other Circuit Protection Devices

The core idea: each device fails differently. Breakers cycle, PTCs hide behind voltage that’s present, fusible links melt quietly, and nothing gets replaced until you find the root cause.

Circuit breakers. Inside is a bimetallic strip and a set of contacts. Too much current heats the strip, it bends, and the contacts open. A cycling breaker cools, closes, and tries again. Breakers go where sudden total loss is unsafe; headlights are the classic example, since flashing lights beat instant darkness on the highway. They also go where surge current is normal: power seats, locks, and windows. Symptom to cause: a load that works, quits, and works again on a rhythm is a breaker reacting to an overload. Find the overload; don’t replace the breaker.

PTC circuit protectors. Positive temperature coefficient means resistance goes up as temperature goes up. A PTC is solid state with no moving parts, installed in series. Excess current heats it, its resistance climbs, and current drops. The symptom is a power window that moves much slower than normal. PTCs often live in the power distribution center.

The PTC trap: the hook payoff. A tripped PTC doesn’t open the circuit. It goes to very high resistance, so voltage is still present at the component and the load looks bad. A multimeter draws almost no current, so it reads near full voltage through a tripped PTC. The PTC won’t reset until voltage is removed. After cooling, the component may work briefly, then slow again. Now go back to the window: the meter read 12.5 volts at the unplugged motor, but load the circuit and the voltage collapses. The fix is to find what tripped the PTC, like a binding regulator, a dragging track, or a shorted motor.

A sharp learner may object that unplugging the motor would let the PTC cool and reset. Your answer: tripped or reset, it doesn’t matter. An unloaded voltage reading can’t tell you either way. Only a loaded test, or voltage drop with the motor running, shows the problem.

Fusible links. A fusible link is a short length of stranded copper, 6 to 9 inches long, with special nonflammable insulation. It is four gauge numbers higher, meaning thinner, than the circuit it protects: a 12 gauge circuit uses a 16 gauge link. Count it out loud: 12, 13, 14,

15, 16. Learners who count four even sizes land on 20, far too small. Links are the backup protection; all current except starter current flows through them, then through the fuses. A link can melt without any fuse blowing. It sits as close to the battery as possible, because the wire between the battery and the link is unprotected. Thick insulation can make a link look bigger than it is, the same lesson as the jumper cable jacket.

Exact link length. This is a red, discussion-only safety slide. Too short and the link won't heat up enough to melt, so it won't protect anything. Too long and it can melt in normal use. Use the exact length, gauge, and type from service information. Never substitute ordinary wire; its insulation burns instead of containing the melt, and that is a harness fire next to the battery.

Mega fuses. Many newer vehicles use bolt-down mega fuses instead of fusible links for high-amperage circuits like charging, high-intensity discharge headlights, heated glass, and multi-circuit feeds. Ratings run 80, 100, 125, 150, 175, 225, 250, and 300 amps. The book's figure caption calls a 300 amp device a maxi fuse, but maxi fuses top out around 80. It's a mega fuse. If a learner catches the caption, credit them. The short version: maxi is a big plug-in blade; mega is bolt-down, 80 amps and up.

Checking links and mega fuses. Look where power is distributed: the starter solenoid battery terminal, power distribution centers, the alternator output, and battery positive. A link can melt with no visible damage. For the stretch test, gently pull each end; if the insulation stretches like a rubber band, the wire inside has melted. You can also check for voltage at both ends: voltage on one end only means the link is open. When whole groups of circuits are dead but the fuses test good, look upstream at the link or mega fuse.

Root cause, then replace. First find out why it failed and repair the fault. Then check service information for exact length, gauge, and type, and install the specified replacement. Mega fuses can fail from vibration, collision, or corrosion; if one is loose, check for heat damage, and replacing it may be the fix. If it failed from excess current, look for collision damage and check every component on that feed. A blown link means a short big enough to beat every downstream fuse. Replace the link without finding the short and you just light the next one.

The green crud. Corroded connections cause intermittents and opens, and the cycle feeds itself. Heat causes expansion, from exhaust or from voltage drop at a poor connection. Condensation forms as the connector cools, and corrosion starts. Then water gets in. The fix is to clean the terminals, confirm the wire-to-terminal connection, and use dielectric grease only if the manufacturer says to. Remind them that dielectric grease is an insulator that seals out water; it doesn't help conduct.

Check for Understanding answers. The breaker cycles, the PTC goes to high resistance and resets when voltage is removed, and the fuse must be replaced. A 10 gauge circuit takes a 14 gauge fusible link, four gauge numbers higher. Insulation that stretches means the wire inside has melted. And the 12.5 volt unloaded reading couldn't prove the circuit good, because the meter draws almost no current. Only a loaded test shows the problem.

Section 5: Terminals and Connectors

The core idea: the terminal makes the electrical connection, the connector makes the mechanical one, and the wrong tool turns a good terminal into an intermittent.

Terminal versus connector. The terminal is the metal end on the wire and makes the electrical connection. The connector is the plastic body and makes the mechanical connection. Terminals snap into the connector and are held there. Male and female halves snap together to complete the circuit, and connectors exposed to weather have a seal. Learners mix these words up constantly, so make them say it back: terminal is metal and electrical, connector is plastic and mechanical.

Locks on locks. Work from the outside in. The connector position assurance clip, or CPA, keeps the latch from releasing by accident. It's often yellow, red, or white, and learners break it if they don't know it's there. The primary latch holds the two halves together. The secondary lock helps hold the terminals in the connector. The lock tang is the small spring tab on each terminal that holds it in its cavity.

Removing a terminal, in four steps:

1. Release the CPA, if equipped.
2. Open the lock and separate the halves.
3. Release the secondary lock, if equipped.
4. With a pick, find the lock tang slot, depress the tang, and gently remove the terminal.

To reinstall, push the terminal in until it clicks, then tug the wire gently. If it backs out, lift the lock tang back out slightly with the pick. The live demo on a junkyard connector happens at the lab station, not during lecture.

Shop reality. These are your field notes. The wrong tool spreads or bends a terminal and causes an intermittent, so use the manufacturer's terminal kit for that connector family. Never force a meter probe into the front of a female terminal; you'll find the problem and create a new one, so back-probe or use the right adapter. Check terminal fit with a matching male terminal: you should feel light drag, and no drag means a spread terminal. A loose terminal heats up and starts the green crud cycle from Section 4.

Check for Understanding answers. The terminal makes the electrical connection. The removal order is release the CPA, separate the halves, release the secondary lock, then depress the lock tang. Prying a female terminal with the wrong tool spreads it, kills its contact tension, and causes an intermittent.

Section 6: Wire Repair

The core idea: any repair under the hood or exposed to the weather must be sealed. That means crimp-and-seal, or solder with adhesive-lined heat shrink. This section feeds the lab directly.

Solder basics. Many manufacturers want bare wire splices and hand crimps soldered. Solder is a tin and lead alloy. Flux cleans the joint and helps solder flow, and electrical solder carries rosin in its core. Acid-core solder is for sheet metal only. Never use it on wiring: acid left in the joint eats the copper from the inside, and the joint fails months later. Match solder diameter to the job; thick solder on a small iron just wicks the heat away.

Solder ratios. Tin is listed first, lead second, and the mix mainly sets the melting point. 60/40 melts at 361 degrees Fahrenheit, 50/50 at 421, and 40/60 at 460. Say it plainly, because learners mix these up: 50/50 is what you see most, and 60/40 is what you reach for, because it melts lowest and flows easiest on small wire. 63/37 is also common and melts at 361. The lead-free slide is a hidden backup. Lead-free solder is mostly tin and melts hotter, around 441 to 450 degrees.

Soldering tools. Electric guns and pencils run 60 to 150 watts. A butane tool is about a 60 watt equivalent and runs roughly half an hour per fill. The whole skill is heat the wire, not the solder. The hot wire melts the solder. Solder melted on the tip and dripped on just sits on cold copper as a cold joint waiting to fail. Tin the tip before you start.

Wire repair and soldering safety. This is a red, discussion-only slide. On a vehicle, disconnect battery negative before cutting or splicing any wire. Side cutters through a live feed is a dead short, possibly on an unfused feed upstream of the fusible links. After reconnecting, check service information for radio, clock, or window relearn. Tips and joints burn, so park an iron in its stand and set a gun on a heat-proof pad; a gun tip can pass 700 degrees. Wear safety glasses because solder spatters. Work with ventilation, wash hands after handling lead solder, and let butane tools cool before stowing them away from fuel and battery gas. And never repair airbag wiring or yellow airbag connectors in this course.

Soldering a splice, in five steps:

1. Prep: slide the heat shrink on first, strip both ends, and join the wires with a splice clip crimp or a lineman splice.
2. With the gun touching the splice, apply solder where the gun meets the wire.
3. When solder starts to flow, hold the gun still and feed solder into the strands opposite the tip.
4. Once it has flowed through, remove the solder first, then the gun, and let the joint cool undisturbed.
5. Check it: shiny is good, dull is a cold joint. Reheat and let it cool slowly.

Step 1 is there on purpose. The most common lab mistake is a perfect joint with the heat shrink still on the bench. Confirm the lab bins hold 60/40 rosin-core, because lead-free joints look dull even when they’re good.

The W crimp. Use the proper crimping tool, not pliers. Most manufacturers call for a W-shaped crimp that forces the strands tight. The open side of the terminal faces the W-shaped side of the jaws. Get that wrong and the jaw crushes the barrel flat instead of rolling the tabs into the strands. Bare hand crimps get soldered, but never solder a crimp-

and-seal connector, because its heat shrink and sealant are the seal. Tug test every crimp with a firm pull, not a yank.

Heat shrink: standard versus adhesive-lined. Standard heat shrink shrinks to about half its diameter, and its ends stay open, so it doesn't stop corrosion. Adhesive-lined, or dual-wall, shrinks to about a third, and its adhesive melts and seals the ends. Chrysler recommends it for any repair exposed to the elements. Tell learners to buy by the words adhesive-lined or dual-wall on the package, not by shrink ratio alone, since ratio and adhesive are separate properties. Heat it with a flameless heat-shrink torch or heat gun; a lighter scorches the tubing and the insulation next to it.

Crimp-and-seal connector, the GM-recommended method:

1. Strip about 5/16 inch, or 8 millimeters, from each wire end.
2. Pick the connector for the wire gauge, insert the wires, and crimp with only the specified crimper so you don't punch through the cover.
3. Heat until the sleeve shrinks and a small bead of sealant shows at both ends.
4. Pass check: a sealant bead at both ends, no bare copper, and a good tug test.

That sealant bead is the visible pass-fail check. No bead means no seal, which means water and green crud. These are not the cheap insulated butt connectors from a parts-store kit. Step 4 covers three of the four sign-off checks; the fourth, the correct fuse with the circuit working, happens on the lab test board.

Which method, where. Crimp-and-seal, used by GM and others, is acceptable anywhere and is the better choice even inside the vehicle. Solder with adhesive-lined heat shrink, Chrysler's method, is acceptable anywhere, including exposed areas. Solder with electrical tape is acceptable inside the vehicle only. Cheap insulated crimps and twist-and-tape are never acceptable. Some manufacturers have no-repair zones, like airbag circuits, where the harness or pigtail gets replaced instead.

Check for Understanding answers. Use rosin-core solder, because acid causes corrosion. A dull, grainy joint is a cold joint; reheat it and let it cool slowly. For a repair near the headlight under the hood, the acceptable methods are crimp-and-seal or solder with adhesive-lined heat shrink. A crimp-and-seal is done right when there's a sealant bead at both ends, no bare copper, and it passes the tug test.

Section 7, the Whole Task, and the Wrap

The core idea: conduit color tells you what you're near, and orange means hands off.

Read the conduit color. Conduit, meaning split-loom and convoluted tubing, covers and protects wiring. Black with a green or blue stripe is high-temperature conduit for use near hot engine parts. Never replace it with plain unstriped conduit, which melts near the exhaust and takes the wires with it. Blue or yellow marks 12 to 42 volt circuits, usually electric power steering. 42 volts isn't a shock hazard, but it can sustain an arc if a live circuit is disconnected. One caution worth saying out loud: in the shop, yellow connectors

and yellow harness covering usually mean airbag circuits. Don’t let “yellow equals 42 volts” be the only thing learners remember.

Orange means hands off. This is a red, discussion-only safety slide, and the scope is recognition only. Orange conduit carries high voltage, above 60 volts, on hybrid and electric vehicles, and a shock can be fatal. In this course learners recognize it and don’t touch, cut, probe, or unplug it. Working on it takes specific training, the manufacturer’s de-powering procedure, and rated high-voltage gloves, which comes in later courses. If a learner finds orange conduit on a shop vehicle, the answer is to stop and get you.

Section 7 Check for Understanding answers. Next to the exhaust manifold, install black conduit with a green or blue stripe. Blue conduit to the steering rack is 12 to 42 volts. Orange conduit on a shop car means stop, hands off, and get the instructor.

Whole task: the trailer harness. This is the rehearsal for tonight’s objective. Give pairs about five minutes, then walk it together. The scenario: trailer lights flicker on a 15 amp circuit with a 22 foot run, and the wire is chafed through under the bumper.

1. What gauge? 22 feet rounds up to the 25 foot column, so 12 gauge. The repair wire also has to match or beat the original.
2. What fuse, with no spec available? 15 divided by 0.8 is 18.75, so the next size up is 20 amps. Stress the condition: when a spec exists, the spec always wins.
3. Which repair methods? The repair is exposed to the elements, so crimp-and-seal or solder with adhesive-lined heat shrink. Not electrical tape.
4. What proves the job is done? The four sign-off checks: tug test, sealed both ends with no bare copper, gauge matches or beats the original, and the circuit works on the correct fuse.

Bonus point: trailer lights live and die on their ground wire, so check it.

What we covered. AWG runs backward, metric runs forward, and longer runs need bigger wire. Grounds complete the circuit, and gauge is the conductor, never the jacket. Fuses protect the wire: test both sides and read the number, not the color. PTCs hide behind voltage that’s present, so test loaded and find the root cause. Weatherproof repairs are crimp-and-seal or solder with adhesive-lined heat shrink. Close by asking each table for one thing they’ll use in lab tonight.

Tonight’s Lab

Three skills get a hands-on sign-off tonight or Thursday: testing a fuse on both sides, removing a terminal without damage, and making soldered and crimp-and-seal splices. Everything else is checked by the online homework and the in-class checks. Learners rotate through stations in pairs.

Station 1: fuse panel. Fuse panel and test lights, for testing fuses on both sides.

Station 2: connectors. Junkyard connectors and pick tools. Do the terminal removal demo here. Every learner pulls and reinstalls one terminal.

Station 3: splice bench. This is where the full objective gets checked. Each pair draws a selection card, picks the gauge from the wire sizing chart and the fuse by the 80/20 rule, and makes the repair. Then they prove it on a powered test board with a bulb load and the fuse they selected. Show the Electrical Wire Repair video here. A side table holds the cut-open cheap and quality jumper cables from Section 2.

The selection cards. Print one set. Every card carries the same rule: use the larger of the chart gauge and the original gauge, and size the fuse at normal current divided by 0.8, next size up. All five combinations keep the wire comfortably able to carry its fuse. 10 A 10 A 10 ft 12 A 12 ga 14 ga 14 ga 15 A 15 A 15 A 15 ft 16 ga 16 ga 16 ga 16 ga 18 ga 18 ga 18 ga 20 A 22 ft 25 ft 25 ft 5 A 7 A 7.5 A Answer: fuse Answer: wire Load Original wire Run

Card	Load	Run	Original wire	Answer: wire	Answer: fuse
A	5 A	10 ft	18 ga	18 ga	7.5 A
B	7 A	25 ft	18 ga	16 ga	10 A
C	10 A	15 ft	16 ga	16 ga	15 A
D	12 A	25 ft	16 ga	14 ga	15 A
E	15 A	22 ft	14 ga	12 ga	20 A

Splice bench supplies:

- Solder guns and irons, with stands and heat-proof pads
- 60/40 rosin-core solder
- Wire strippers
- W-crimp and crimp-and-seal crimpers
- Crimp-and-seal connectors and adhesive-lined heat shrink
- A flameless heat-shrink torch or heat gun
- Wire spools in the lab gauges
- One printed wire sizing chart and one fuse color chart per pair

Make sure the powered test board has a fuse holder and a bulb load for every pair.

Lab safety. Safety glasses on, and battery negative off before cutting any wire on a vehicle.

The sign-off, one more time: tug test, sealed at both ends with no bare copper, gauge matches or beats the original, and the circuit works on the correct fuse. Thursday finishes

sign-offs, then review and debrief. The online homework is due at the end of the week, and next week is wiring schematics.

Where the Textbook and Homework Disagree With Your Slides

Ten spots where a learner may bring up the book or an online homework item that doesn't match the slide. Each one has a short answer ready.

1. Wire diameter chart. The book's wire diameter chart has footnote digits merged into the numbers, so 20 gauge prints as 0.03196118 instead of 0.03196. The hidden backup slide has the corrected values. If a learner shows a long number, that's why.

2. Jumper cable minimum. The book says 4 to 2/0 gauge, then later says 6 gauge or larger. You teach 4 gauge minimum. If an online homework item uses 6 gauge, treat it as the book's looser number.

3. Battery cable sizes. One section says 4, 2, or 1/0; another says 4, 2, or 1. The slide says 4 gauge and larger, which covers both.

4. Trailer wire example. The book says a run over 25 feet should move to 12 gauge. The wire sizing chart actually moves a 15 amp circuit to 12 gauge past 20 feet, so the slide follows the chart.

5. Fusible link sizing. The book says four wire sizes smaller. The slide says four gauge numbers higher, meaning thinner, because "smaller" in a backward system sounds like a bigger wire to a novice. A 12 gauge circuit takes a 16 gauge link.

6. Mega versus maxi. The book's figure caption calls a 300 amp fuse a maxi fuse. Maxi fuses top out around 80 amps, so it's a mega fuse.

7. Fuse colors. The book's blade chart lists low-amp colors that don't match the industry standard: 1 amp dark green, both 2.5 amp purple and 3 amp violet, 9 amp orange, and 14 amp black. They're not on the slide. If an online homework item asks, go with the book.

8. Lead-free melting point. The book prints 95/5 tin-antimony as 450 degrees Fahrenheit, 245 Celsius. 450 Fahrenheit is actually 232 Celsius. The hidden backup slide uses 232.

9. 50/50 versus 60/40. Not an error, just easy to confuse. 50/50 is the most common; 60/40 is the one to use.

10. Skin effect. Taught as the book states it, so the slide matches the wording learners will see on the online quiz.

One note on the objective: its criterion requires the repair to be sealed at both ends. Without that, a solder-and-tape splice under a bumper would pass sign-off.

Before Class

Six things to confirm or prep before the session.

- Confirm the session date and room.
- Confirm the online homework due date.
- Fill in the task sheet numbers for each station, in the last slide's speaker notes.
- Print the selection cards, plus one wire sizing chart and one fuse color chart per pair.
- Check the splice bench: 60/40 rosin-core solder in the bins, a powered test board with a fuse holder and bulb load for every pair, and a cut-open cheap and quality jumper cable for the side table.
- Check the run time of the fuse testing video.

One reminder for after class: the speaker notes ship inside the slide file. Export to PDF or strip the notes before posting the deck to the LMS.

Lab: EPS Diagnostic Scenarios

ASE A4 · Steering Systems Diagnosis and Repair
Will Wallace

Name:	Date:	Vehicle:

Objective

Given a customer complaint and captured scan data for an electric power steering system, name the most probable fault and the next diagnostic test to perform, without naming a part to replace, for at least three of four scenarios. Maps to four of the module's enabling objectives.

This is a paper station. No vehicle required. Use service information to look up any diagnostic trouble code description you are given. Answer in complete sentences.

> **Ground rule**
> *Every answer names a test, not a part. 'Replace the module' is not a diagnosis. 'Measure available voltage at the module connector' is.*

Scenario 1: No Assist at All (25 pts)

Customer: steering went heavy on the way to work and stayed that way. Warning lamp is on.

Captured data:

- Steering module: communicates normally with the scan tool
- One stored DTC, description: Steering Assist Motor Circuit
- Torque Sensor Signal 1 and Signal 2: present and moving in opposite directions with input
- Steering position sensor: signals present, tracking normally
- Battery voltage, engine running: 14.1 V

1. What does the torque sensor data tell you that you can rule out?

2. What is your most probable fault?

3. What is the next test you perform, and where do you place your meter leads?

Scenario 2: Assist One Direction Only (25 pts)

Customer: it helps me turn left but I have to fight it to turn right.

Captured data:

- No stored DTCs

- At rest: Signal 1 = 2.51 V, Signal 2 = 2.49 V
- Turning left: Signal 1 = 1.85 V, Signal 2 = 3.15 V
- Turning right: Signal 1 = 2.52 V, Signal 2 = 2.48 V
- Battery voltage, engine running: 13.9 V

1. Which reading is wrong, and how do you know?

---

2. Which circuit or component are you testing next?

---

3. Why did this fault not set a diagnostic trouble code?

Scenario 3: Intermittent Heavy Steering (25 pts)

Customer: it gets hard to steer when I am backing the trailer into the driveway, then it is fine again by the time I go out.

Captured data:

- No stored or pending DTCs
- All sensor signals within specification when tested
- Battery and charging system test: pass
- Condition cannot be reproduced on a short test drive
- Condition reproduces after four minutes of continuous low-speed maneuvering

1. What is your diagnosis?

---

2. Is this a repair or a customer conversation? Defend your answer.

---

3. What is the one piece of evidence that most strongly supports your conclusion?

Scenario 4: Module Will Not Communicate (25 pts)

Customer: the shop down the road said the steering computer is bad and quoted me two thousand dollars.

Captured data:

- Scan tool: no communication with the steering module
- All other modules on the network communicate normally
- Warning lamp on, no assist

- EPS high-amperage fuse: visually intact
- Battery voltage, engine running: 14.0 V

1. What do you prove before you agree the module has failed? List two measurements.

---

2. What does it tell you that every other module communicates normally?

---

3. A visually intact fuse is not a passed fuse. What test settles it?

Instructor Verification

Instructor initials and date:

Total: _____ / 100

BATTERIES | ON-VEHICLE

Lab 1: Read the Battery

Inspect it, identify it, and check it against spec | Pairs | 45 minutes

Name _____ **Date** _____

Partner(s) _____ **Vehicle / Bench** _____

WHAT YOU WILL BE ABLE TO DO

Inspect a battery installation and call each item OK or Not OK.
Identify the battery's construction type (flooded, EFB, or AGM) from its label and features.
Read the battery's ratings and age, and decide if it meets the vehicle's specification.

BATTERY SAFETY

Safety glasses on before you open the hood. Battery acid can be on the case and terminals.
Do not disconnect any battery cable in this lab. Many vehicles lose module memory or need relearns.
Keep metal tools off the battery top. A wrench across the posts makes a dead short.

You need

- An assigned shop vehicle, safety glasses, gloves, flashlight
- Service information, the owner's manual, or a parts store application chart (laptop or phone)

Part A: Find and Inspect (10 minutes)

Find the battery. It may be under the hood, in the trunk, or under a seat. If it is inside the vehicle, look for the vent tube.

☐ **1.** Record where the battery is mounted.

☐ **2.** Check the **hold-down**. Push on the battery. It should not move.

☐ **3.** Check the **case** for cracks, bulging, or wet acid on the top or sides.

☐ **4.** Check the **terminals and cables** for corrosion (white or green crust), loose clamps, and frayed insulation.

☐ **5.** If the battery is inside the cabin or trunk, check that the **vent tube** is connected and routed outside.

Item	OK / Not OK	What you saw
Battery location		
Hold-down		
Case		
Terminals and cables		
Vent tube (if inside the vehicle)		

1. Why does a loose hold-down shorten battery life? Use the words **vibration** and **shed** in your answer.

Part B: Read the Label (15 minutes)

Everything you need is printed on the battery. Some numbers are on the top label, some on the side. Use the flashlight.

- ☐ **1.** Look for removable vent caps. Look for the words **AGM**, **EFB**, **VRLA**, **non-spillable**, or **maintenance-free** on the label.
- ☐ **2.** Decide the battery type: **Flooded**, **EFB**, or **AGM**. If you can't tell, write Unknown and say why.
- ☐ **3.** Record every rating you can find. Write **Not listed** if a rating isn't on the label.
- ☐ **4.** Find the **date code** (sticker or stamped code). Many use a letter for the month (A = January) and a number for the year. Ask your instructor if you can't decode it.

Label item	What the label says
Battery type and how you knew	
BCI group size	
Cold-Cranking Amps (CCA)	
Cranking Amps (CA) or Marine Cranking Amps (MCA)	
Reserve Capacity (RC), minutes	
Amp-hours (A-H)	
Date code and battery age	
Charge indicator (green eye)? Y / N	

2. The label lists both CCA and CA. Which number is higher, and why?

3. Normal battery life is 3 to 7 years. Based on its age, what would you tell this customer?

Part C: Check It Against Spec (12 minutes)

A replacement battery must fit the tray, reach the cables, and meet or beat the original CCA rating.

- ☐ **1.** Look up the correct **group size** and **minimum CCA** for this vehicle in service information, the owner's manual, or a parts application chart.
- ☐ **2.** Record where you found it.
- ☐ **3.** Compare the spec to what is installed.
- ☐ **4.** Note whether the vehicle has **stop/start**. If it does, record the battery type it requires.

	Specification	Installed	Meets spec? Y / N
Group size			
CCA			
Battery type (if specified)			

Where you found the spec: _____

4. Someone installed a battery with a lower CCA than spec. What might the customer notice on the first cold morning?

5. A vehicle with stop/start came from the factory with an AGM battery. Why is a regular flooded battery a bad replacement?

Part D: Compare Three Batteries (8 minutes)

Trade data with two other pairs who inspected different vehicles. Fill in their numbers.

Vehicle	Type	Group size	CCA	RC	Age
Yours					

6. All three batteries are 12 V, but their CCA ratings differ. What is different inside the higher-CCA battery? (Think plates.)

7. Which of these batteries could be mounted on its side? How do you know?

STOP: INSTRUCTOR CHECK

Show your tables and answers. Initials: _____

BATTERIES | ON-VEHICLE AND BENCH

Lab 2: State of Charge Three Ways

Voltage, the green eye, and specific gravity | Pairs | 50 minutes

Name _____ **Date** _____

Partner(s) _____ **Vehicle / Bench** _____

WHAT YOU WILL BE ABLE TO DO

Measure open circuit voltage the right way and convert it to state of charge.
Read a built-in charge indicator and explain why it can't be trusted alone.
Measure specific gravity in all six cells and find a weak cell.

STATE OF CHARGE CHART AT 80°F

100%: 12.6 V or more, SG 1.265 **75%:** 12.4 V, SG 1.225 **50%:** 12.2 V, SG 1.190
25%: 12.0 V, SG 1.155 **Discharged:** 11.9 V or less, SG 1.120 or less

ACID AND HYDROGEN

Safety glasses and gloves for every step. Electrolyte is sulfuric acid.
No sparks or flames near the battery. Charging and gassing release hydrogen, which is explosive.
Never test, charge, or jump a battery that is frozen or bulging. Tell your instructor.
Acid on skin or bench: flush with water. Neutralize spills with baking soda and water.

You need

- An assigned shop vehicle, DMM, safety glasses, gloves
- Bench station (if available): flooded battery with removable caps, battery hydrometer, thermometer, water and baking soda, shop towels

Part A: Open Circuit Voltage (12 minutes)

A battery that was just charged or driven holds a **surface charge** that reads high. Remove it first, or the reading will fool you.

- ☐ **1.** Key OFF, doors closed, all accessories off. DMM on **DC volts**.
- ☐ **2.** Red lead on the positive post, black lead on the negative post. Touch the **posts**, not the cable clamps. Record the voltage.
- ☐ **3.** Remove surface charge: turn the headlights on (engine off) for **1 minute**, then turn them off.
- ☐ **4.** Wait **2 minutes**. Measure again and record.
- ☐ **5.** Use the state of charge chart to find the state of charge.

Measurement	Reading
Voltage before removing surface charge	
Voltage after headlights and 2-minute wait	
State of charge from the chart	

1. Did the voltage drop after the headlights? What does that tell you about the first reading?

2. The battery reads 12.2 V. A classmate says "12 point 2, it's a 12 V battery, it's fine." What do you tell them?

Part B: The Green Eye (8 minutes)

If your vehicle's battery has no charge indicator, use one from the instructor bin or a classmate's vehicle.

- ☐ **1.** Wipe the sight window clean. Look straight down into it with the flashlight.
- ☐ **2.** Record the color: **green**, **dark/black**, or **clear/yellow**.
- ☐ **3.** Record what that color means.
- ☐ **4.** Compare it to your Part A state of charge.

Indicator	Result
Color	
What it means	
Agrees with the voltage reading? Y / N	

3. Give two reasons a green eye can show green on a battery that won't crank the engine.

Part C: Specific Gravity, Cell by Cell (18 minutes, bench)

Sealed batteries (AGM and most maintenance-free) can't be tested this way. Use the flooded bench battery with removable caps. If no bench station is set up, go to Part D.

- ☐ **1.** Glasses and gloves on. Remove the vent caps. Check that electrolyte covers the plates in every cell. If not, stop and tell your instructor.
- ☐ **2.** Squeeze the hydrometer bulb, put the tip in **cell 1**, and draw in electrolyte until the float lifts free. Do not let it touch the top or sides.
- ☐ **3.** Hold it straight up at eye level and read the float where the liquid surface crosses it. Record it.
- ☐ **4.** Return the electrolyte to **the same cell** it came from. Never move electrolyte between cells.
- ☐ **5.** Repeat for cells 2 through 6. Measure the electrolyte temperature with the thermometer.
- ☐ **6.** Temperature correction: **add 0.004 for every 10°F above 80°F; subtract 0.004 for every 10°F below.**
- ☐ **7.** Find the **spread**: highest corrected reading minus lowest. A spread over **0.050** means a weak cell.

☐ **8.** Reinstall all caps. Wipe the case with baking soda and water, then rinse the hydrometer.

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
Reading						
Corrected						

Electrolyte temperature: _____ °F Spread (high minus low): _____ Weak cell? Y / N, which one: _____

4. Higher specific gravity means more acid in the electrolyte. Where did the acid go in a cell that reads low?

5. Why must electrolyte go back into the same cell it came from?

Part D: Back to the Slow-Crank Truck (12 minutes)

This is the truck from the lecture. Another shop replaced the starter, and it still cranks slow on cold mornings. Here is what a tech recorded at 80°F.

Test	Result
Open circuit voltage (surface charge removed)	12.4 V
Charge indicator (built into cell 1)	Green
Specific gravity, cells 1 to 6	1.265 | 1.270 | 1.260 | 1.180 | 1.265 | 1.265

6. What is the spread? Which cell is weak?

7. The green eye said the battery was fine. Why was it wrong this time?

8. The voltage only dropped to 12.4 V. Why didn't voltage alone catch this problem?

9. What should the first shop have done before replacing the starter?

STOP: INSTRUCTOR CHECK
Show your tables and answers. Initials: _____

Job Aid: Alignment Angle Quick Reference

Keep this at the alignment rack. Every tolerance on this sheet is a general rule; the manufacturer's specification always wins.

1. The Angles at a Glance

Angle	What it is	Wears tires	Causes pull	Adjustable
Camber	Wheel tilt in or out, viewed front or rear	Yes, one tire, one edge	Yes, to most positive	Often
Caster	Steering axis tilt fore or aft, viewed from side	Not straight ahead	Yes, to most negative	Sometimes
Toe, front	Front vs rear distance across a tire pair	Yes, both tires, same edge	No	Always
Toe, rear	Same, on the rear axle	Yes, diagonal wipe	Sets thrust angle	Often
SAI	Vertical to a line through upper and lower pivots	No	No	Never
Included angle	SAI plus camber, front wheels only	No	No	Never
Scrub radius	Steering axis to tire centerline at the road	Indirectly	No	Never
Turning radius	Toe-out on turns, from steering arm angle	Scuffs in turns	No	Never
Setback	One front wheel behind the other	No	Yes, to short side	Never
Thrust angle	Rear wheel direction vs geometric centerline	Through toe	Yes	Via rear toe

2. Tolerances to Know Cold

Check	Rule
Camber, side to side	Maximum 0.5 degree spread
Caster, side to side	Maximum 0.5 degree spread
Included angle, side to side	Within 0.5 degree
SAI, side to side	Difference over about 1.5 degrees indicates a problem
Turning radius	Within about 1.5 degrees of specification
Steering wheel angle	Typically within plus or minus 3 degrees
Watch for	A reading inside its own range can still fail the spread rule

Spread
Side-to-side difference is called spread, or cross caster and cross camber. Check it every time, on every angle that has a rule.

3. Pull Direction Rules

Condition	Vehicle pulls toward
Unequal camber	The side with the MORE POSITIVE camber
Unequal caster	The side with the MORE NEGATIVE caster
Setback	The side with the SHORTER wheelbase
Thrust angle	Follows the thrust line; steering wheel goes off center
Incorrect front toe	Does not pull. Wears tires instead.
Defective tire	The side the bad tire is on. Cross-swap to confirm.
Road crown	Toward the outer edge of the lane. Not a defect.

4. Wear Pattern to Angle

What you see or feel	Most likely cause
One tire, outside edge only	Positive camber on that wheel
One tire, inside edge only	Negative camber on that wheel
Both front tires, outside edges	Excessive toe-in
Both front tires, inside edges	Excessive toe-out
Feather smooth sliding outside to inside	Toe-out
Feather smooth sliding inside to outside	Toe-in
Diagonal wipe, rear tires	Incorrect rear toe
Scuffed wear, squeal in turns only	Turning radius, check for a bent steering arm
Cupped or scalloped	Not alignment. Balance, shocks, or a bent wheel.
Center wear only	Overinflation
Both edges, center smooth	Underinflation

5. The Bent Part Decision Rule

Camber	Included angle	Conclusion
Out of spec	Correct, within 0.5 degree	Knuckle and spindle are NOT bent. Adjust.
Out of spec	Also out of spec	A part is bent. Replace, do not adjust.
Out on BOTH sides	Correct on BOTH sides	Suspect a shifted cradle or subframe.
Cannot be adjusted	Check it before condemning anything	Included angle tells you what to do next.

Included angle = SAI + camber. Positive camber, add it. Negative camber, subtract it. Set camber correctly before evaluating SAI.

6. Order of Operations

Step	Do this	Why
1	Pre-alignment inspection and tire pressures	You cannot align looseness
2	Ride height, all four corners	Specs assume correct ride height
3	Read the tires	Free evidence, gone once they are replaced
4	Measure all four wheels	Rear wheels set the direction the vehicle goes
5	Adjust caster and camber together	Changing caster moves camber
6	Adjust toe LAST	Changing caster and camber moves toe
7	Center the wheel with the tie rods	Never by reindexing the steering wheel
8	Recalibrate steering angle sensor if required	Feeds stability and driver assist systems