Contents

Preface 11
About the Author 13

Section 1: Safety and Communication 15

Chapter 1: General Shop Safety 17
Introduction 17
Occupational Safety and Health Act and Environmental Protection Agency 17
Shop Hazards 17
Shop Safety Rules 18
Smoking, Alcohol, and Drugs in the Shop 20
Air Quality 20
Shop Safety Equipment 20
Shop Layout 23
Hazardous Waste Disposal 24
Review Questions 26

Chapter 2: The Automotive Business 28
Introduction 28
Types of Automotive Repair Shops 28
Successful Dealership Management 29
Automatic Transmission Rebuilders Association (ATRA) 30
Mobile Air Conditioning Society Worldwide (MACS Worldwide) 31
Automotive Service Association (ASA) 31
International Automotive Technicians Network (iATN) 32
Review Questions 32

Chapter 3: Basic Shop Operation 34
Introduction 34
Service Writers 34
Cashiers 35
Service Manager 35
Shop Foreman 35
Repair Orders 35
Technicians and Repair Orders 36
Employee to Employer Obligations 36
Employer to Employee Obligations 37
Job Responsibilities 38
National Institute for Automotive Service Excellence (ASE) 38
National Automotive Technicians Education Foundation (NATEF) 39
Job Application 40
Customer Relations 40
Review Questions 41

Chapter 4: Tools and Equipment 43
Introduction 43
Common Hand Tools 43
Files, Taps, and Dies 47
Gear and Bearing Pullers 48
Bushing and Seal Pullers and Drivers 48
Power Tools and Shop Equipment 49
Electrical and Electronic Test Equipment 53
Review Questions 58

Chapter 5: Tool and Equipment Safety 60
Introduction 60
Electrical Safety 60
Gasoline Safety 60
Fire Safety 61
Using a Fire Extinguisher 61
Vehicle Operation 62
Housekeeping Safety 62
Air Bag Safety 63
Lifting and Carrying 63
Hand Tool Safety 64
Vehicle Lift (Hoist) Safety 64
Hydraulic Jack and Safety Stand Safety 65
Power Tool Safety 66
Compressed-Air Equipment Safety 66
Cleaning Equipment Safety and Environmental Considerations 67
Handling Shop Wastes 68
Interpreting Material Safety Data Sheets (MSDS) 69
Review Questions 70
Section 2: Basic Shop Procedures, Measurements, and Fasteners 73

Chapter 6: Basic Shop Procedures 75
Introduction 75
Using Shop Tools and Equipment 75
Connecting and Using an Impact Wrench 75
Using a Torque Wrench 78
Using Gear, Bearing, and Seal Pullers 78
Removing Broken Studs and Screws 79
Removing Damaged Nuts 81
Using an Acetylene Torch for Heating 81
Checking and Changing Respirator Filters 83
Jump Starting a Vehicle with a Discharged Battery 83
Review Questions 84

Chapter 7: Measuring Systems, Measurements, and Fasteners 86
Introduction 86
Measuring Systems 86
Precision Measurements 87
Fasteners 91
Review Questions 94

Section 3: Service Information 97

Chapter 8: Service Information 99
Introduction 99
Types of Service Information 99
Owner’s Manual 99
Manufacturer’s Service Manual 100
Troubleshooting and Diagnostic Tables 104
Generic Service Manuals 105
Electronic Service Information 105
Computer Software 105
Service Bulletins 106
Labor Estimating Guides 106
Vehicle Service Decals and Warning Labels 107
Review Questions 107

Chapter 9: Using Service Information 109
Introduction 109
Vehicle Identification Number (VIN) Interpretation 109
Locating Capacities and Fluid Requirements in a Service Manual 111
Locating Vehicle Specifications and Maintenance Schedules in a Service Manual 113
Using Generic Service Manuals 115
Review Questions 116

Section 4: Engine Principles and Systems 119

Chapter 10: The Four-Stroke Cycle and Cylinder Arrangements 121
Introduction 121
Engine Cycles 121
The Intake Stroke 121
The Compression Stroke 122
The Power Stroke 123
The Exhaust Stroke 123
Diesel Engine Principles 123
Cylinder Arrangements 125
Valve Arrangements 126
Vehicles with Alternate Power Sources 127
Review Questions 130

Chapter 11: Engine Oil and Lubrication Systems 132
Introduction 132
Engine Oil Rating and Classification 133
Oil Pumps 135
Oil Filter 136
Lubrication System Purpose and Operation 137
Review Questions 138

Chapter 12: Engine Lubrication System Maintenance, Diagnosis, and Service 140
Introduction 140
Changing Engine Oil and Filter 140
Oil Leak Diagnosis 141
Diagnosing Oil Pressure Indicators 142
Resetting Change Oil Warning Messages 143
Diagnosis of Excessive Oil Consumption 144
Oil Pressure Diagnosis 144
Oil Pressure Testing 144
Oil Pump Service 145
Oil Jet Valves 145
Review Questions 146

Chapter 13: Engine Coolant and Cooling Systems 148
Introduction 148
Engine Coolant 148
Radiators and Coolant Recovery Systems 149
Heater Core 151
Hoses 151
Water Pump 151
Water Pump Drive Belts 152
Thermostat 153
Cooling Fans 154
Electric-Drive Cooling Fans 155
Cooling System Operation 155
Temperature Indicators 157
Review Questions 158

Chapter 14: Engine Cooling Systems
Maintenance, Diagnosis, and Service 160
Introduction 160
Cooling System Maintenance 160
Coolant Contamination 162
Cooling System Diagnosis 162
Draining the Cooling System 162
Filling the Cooling System 162
Cooling System Flushing 163
Diagnosis of Improper Operating Temperature 164
Thermostat Testing 164
Pressure Cap Diagnosis and Cooling System Leak Diagnosis 165
Cooling System Service 165
Review Questions 168

Chapter 15: Intake and Exhaust Systems 170
Introduction 170
The Air Induction System 170
Air Intake Ductwork 170
Air Cleaner/Filter 171
Intake Manifold 172
Vacuum Basics 174
Vacuum System 174
Exhaust System Components 174
 Catalytic Converters 175
Exhaust System Purpose and Operation 178
Review Questions 179

Chapter 16: Intake and Exhaust System
Maintenance, Diagnosis, and Service 181
Introduction 181
Intake System Maintenance 181
Intake System Diagnosis 182
Intake System Service 184
Exhaust System Maintenance 185
Exhaust System Diagnosis 185
Exhaust System Restriction Diagnosis 185
Converter Diagnosis 186
Exhaust System Service 186
Review Questions 188

Section 5: Electrical Systems 191

Chapter 17: Basic Electricity and Electric Circuits 193
Introduction 193
Atomic Structure 193
Elements, Compounds, and Molecules 194
Electric Current Flow 194
Electric Circuit Measurements 195
Ohm’s Law 196
Voltage Drop 196
Series Circuit 196
Parallel Circuit 196
Series-Parallel Circuit 197
Electromagnets 197
Electromagnetic Induction 198
Review Questions 198

Chapter 18: Light Circuits 200
Introduction 200
Lamps 200
Sealed Beam Headlights 201
Halogen Headlights 202
High Intensity Discharge (HID) Headlights 203
Headlight and Dimmer Switches 203
Headlight and Park Light Circuits 205
Concealed Headlight Systems 208
Tail Light, Stop Light, Signal Light, and Hazard Warning Light Circuits 208
Interior Lights 211
Daytime Running Lights 211
Backup Lights 212
Review Questions 212

Chapter 19: Light Circuit Maintenance, Diagnosis, and Service 214
Introduction 214
Headlight Maintenance, Diagnosis, and Service 214
Tail Light, Stop Light, and Park Light Circuit Maintenance, Diagnosis, and Service 219
Signal Light and Hazard Warning Light Circuit Maintenance, Diagnosis, and Service 220
Testing Bulbs and Fuses 222
Review Questions 222

Chapter 20: Indicator Lights and Gauges 224
Introduction 224
Oil Pressure Indicator Lights 224
Engine Temperature Warning Lights 224
Charge Indicator Lights 225
Brake Warning Light 226
Types of Gauges 226
Instrument Voltage Limiters 229
Speedometers and Odometers 230
Tachometers 231
Voltmeters and Ammeters 231
Review Questions 232
Chapter 21: Indicator Light and Gauge Maintenance, Diagnosis, and Service

Introduction 234
Indicator Light Maintenance, Diagnosis, and Service 234
Charge Indicator Light Maintenance, Diagnosis, and Service 236
Brake Warning Light Maintenance, Diagnosis, and Service 237
Gauges and Related Circuit Maintenance, Diagnosis, and Service 237
Voltmeter and Ammeter Maintenance, Diagnosis, and Service 239
Speedometer and Odometer Maintenance, Diagnosis, and Service 239
Tachometer Maintenance, Diagnosis, and Service 240
Review Questions 240

Section 6: Engine Electrical Systems 243

Chapter 22: Battery and Starting Systems

Introduction 245
Battery Design 245
Battery Operation 246
Low-Maintenance Batteries 248
Maintenance-Free Batteries 248
Battery Ratings 248
Starting Motor Electromagnetic Principles 249
Starter Armature Design 250
Starter Field Coil Design 250
Solenoids 251
Magnetic Switches 253
Starter Drives 254
Review Questions 255

Chapter 23: Battery and Starting System Maintenance, Diagnosis, and Service 257

Introduction 257
Battery Maintenance 257
Battery Diagnosis and Service 258
Starting Motor Maintenance 262
Starting Motor Diagnosis 263
Starting Motor and Solenoid Diagnosis and Testing 263
Starting Motor Service and Inspection 264
Review Questions 265

Chapter 24: Charging Systems 267

Introduction 267
Alternator Design 267
Rotor 267
Stator 268
Diodes 269
Alternator Operation 270
Voltage Regulator Operation 272
Review Questions 274

Chapter 25: Charging System Maintenance, Diagnosis, and Service 276

Introduction 276
Alternator and Voltage Regulator Maintenance 276
Charging System Diagnosis 278
Scan Tool Diagnosis of Charging Systems 279
Charging Circuit Voltage Drop Testing 281
Alternator Service and Inspection 281
Review Questions 281

Chapter 26: Ignition Systems 283

Introduction 283
Spark Plugs 283
Distributor Ignition (DI) Systems 285
Distributor Advances 288
Computer-Controlled Spark Advance 290
Electronic Ignition (EI) Systems 290
Coil-On-Plug and Coil-Near-Plug Ignition Systems 293
Review Questions 294

Chapter 27: Ignition System Maintenance, Diagnosis, and Service 296

Introduction 296
Spark Plug Maintenance, Diagnosis, and Service 296
DI System Maintenance, Diagnosis, and Service 298
Checking and Adjusting Ignition Timing 302
EI Maintenance, Diagnosis, and Service 303
Coil-On-Plug and Coil-Near-Plug Ignition System Maintenance, Diagnosis, and Service 305
Review Questions 305

Section 7: Engine Control Systems 307

Chapter 28: Engine Control Computers and Output Controls 309

Introduction 309
Analog Voltage Signals 309
Digital Voltage Signals 310
Section 9: Heating and Air Conditioning Systems 385

Chapter 36: Heating and Air Conditioning Systems 387
Introduction 387
Heating System Design 387
Heat Absorption Principles 388
Air Conditioning Refrigerants 389
R-12 and the Ozone Layer 389
R-134a Refrigerant 389
Alternate Refrigerants 389
Refrigerant Oils 390
Refrigerant Recovery and Recycling Standards 390
Refrigeration System Operation and Controls 390
Manual A/C Systems 396
Semi-Automatic A/C Systems 397
Automatic A/C Systems 397
Review Questions 398

Chapter 37: Heating and Air Conditioning Maintenance, Diagnosis, and Service 400
Introduction 400
Heating System Maintenance, Diagnosis, and Service 400
Air Conditioning (A/C) System Maintenance 400
Air Conditioning (A/C) System Diagnosis 402
Air Conditioning (A/C) System Service 406
Retrofitting R-12 Systems to R-134a Systems 410
Review Questions 412

Section 10: Tires and Wheels 415

Chapter 38: Tires, Wheels, and Hubs 417
Introduction 417
Tire Design 417
Tire Ply and Belt Design 419
Tire Ratings 419
All-Season and Specialty Tires 421
Replacement Tires 422
Run-Flat Tires 422
Tire Valves 422
Compact Spare Tires 423
Tire Contact Area 424
Tire Placard and Inflation Pressure 424
Tire Pressure Monitoring Systems 425
Tire Motion Forces 426
Wheel Rims 426
Static Wheel Balance Theory 427
Dynamic Wheel Balance Theory 428
Wheel Bearings 429
Wheel Bearing Seals 431
Wheel Bearing Hub Assemblies 432
Rear Axle Bearings 433
Bearing Lubrication 434
Review Questions 435

Chapter 39: Tire, Wheel, and Hub Maintenance, Diagnosis, and Service 437
Introduction 437
Tire Maintenance 437
Tire Diagnosis 438
Wheel and Tire Service 439
Wheel Rim Service 443
Tire and Wheel Balancing 445
Wheel Bearing Maintenance 447
Wheel Bearing Diagnosis 452
Wheel Hub Unit Diagnosis 453
Rear Axle Bearing and Seal Service, Rear-Wheel Drive Vehicles 453
Review Questions 456

Section 11: Drive Shafts, Drive Axles, and Clutches 457

Chapter 40: Drive Shaft, Drive Axle, and Universal Joint Maintenance, Diagnosis, and Service 459
Introduction 459
Drive Shaft Design 459
Drive Shaft Purpose 460
Types of Drive Shafts 461
Universal Joints 463
Drive Axle Design 465
Drive Axle Purpose 467
Types of CV Joints 468
Drive Shaft and Universal Joint Maintenance 469
Drive Shaft and Universal Joint Diagnosis 471
Drive Shaft and Universal Joint Service 472
Drive Axle and CV Joint Maintenance 474
Drive Axle and CV Joint Diagnosis 476
Drive Axle and CV Joint Service 477
Review Questions 480
<table>
<thead>
<tr>
<th>Chapter 41: <strong>Clutch Maintenance, Diagnosis, and Service</strong></th>
<th>482</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction 482</td>
<td>Accumulators, Modulators, Thrust Washers, Bushings, and Seals 523</td>
</tr>
<tr>
<td>Clutch Disc Design 482</td>
<td>Electronic Transmission and Transaxle Controls 525</td>
</tr>
<tr>
<td>Flywheel Design 483</td>
<td>Final Drives and Differentials 526</td>
</tr>
<tr>
<td>Pressure Plate Assembly Design 484</td>
<td>Four-Wheel Drive (4WD) 528</td>
</tr>
<tr>
<td>Clutch Release Bearing and Lever 486</td>
<td>All-Wheel Drive 528</td>
</tr>
<tr>
<td>Clutch Linkages 487</td>
<td>Torque Converter Maintenance and Diagnosis 528</td>
</tr>
<tr>
<td>Clutch Operation 488</td>
<td>Torque Converter Service 531</td>
</tr>
<tr>
<td>Clutch Maintenance 489</td>
<td>Automatic Transmission and Transaxle Maintenance 532</td>
</tr>
<tr>
<td>Clutch Diagnosis 490</td>
<td>Automatic Transmission and Transaxle Diagnosis 533</td>
</tr>
<tr>
<td>Clutch Service 492</td>
<td>Automatic Transmission and Transaxle Service 535</td>
</tr>
<tr>
<td>Review Questions 492</td>
<td>Review Questions 538</td>
</tr>
</tbody>
</table>

| Section 12: **Manual and Automatic Transmissions and Transaxles** | 495 |

<table>
<thead>
<tr>
<th>Chapter 42: <strong>Manual Transmission and Transaxle, Maintenance, Diagnosis, and Service</strong></th>
<th>497</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction 497</td>
<td>Manual Transmission and Transaxle Maintenance 505</td>
</tr>
<tr>
<td>Gears 497</td>
<td>Manual Transmission and Transaxle Diagnosis 506</td>
</tr>
<tr>
<td>Gear Ratios 497</td>
<td>Manual Transmission and Transaxle Service 508</td>
</tr>
<tr>
<td>Synchronizers 498</td>
<td>Review Questions 509</td>
</tr>
<tr>
<td>Transmission Types 500</td>
<td>Manual Transmission and Transaxle Lubrication 504</td>
</tr>
<tr>
<td>Transmission Operation 500</td>
<td>Manual Transmission and Transaxle Maintenance 505</td>
</tr>
<tr>
<td>Transaxle Design and Operation 503</td>
<td>Manual Transmission and Transaxle Diagnosis 506</td>
</tr>
<tr>
<td>Manual Transmission and Transaxle</td>
<td>Manual Transmission and Transaxle Service 508</td>
</tr>
<tr>
<td>Lubrication 504</td>
<td>Review Questions 509</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 43: <strong>Automatic Transmission and Transaxle Maintenance, Diagnosis, and Service</strong></th>
<th>511</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction 511</td>
<td>Brake System Maintenance 560</td>
</tr>
<tr>
<td>Torque Converter Purpose and Design 511</td>
<td>Brake System Diagnosis 561</td>
</tr>
<tr>
<td>Torque Converter Operation 512</td>
<td>Brake Service 561</td>
</tr>
<tr>
<td>Planetary Gearset Design and Operation 514</td>
<td>Antilock Brake System Maintenance 568</td>
</tr>
<tr>
<td>Multiple-Disc Clutches 516</td>
<td>ABS Diagnosis, OBD I Vehicles 569</td>
</tr>
<tr>
<td>Bands and One-Way Clutches 517</td>
<td>ABS Diagnosis, OBD II Vehicles 570</td>
</tr>
<tr>
<td>Oil Pump and Pressure Regulator Valve 518</td>
<td>Wheel Speed Sensor Diagnosis 571</td>
</tr>
<tr>
<td>Governors 520</td>
<td>ABS Service 571</td>
</tr>
<tr>
<td>Throttle Linkages and Throttle Valves 520</td>
<td>Review Questions 572</td>
</tr>
<tr>
<td>Valve Body and Shift Valves 520</td>
<td></td>
</tr>
</tbody>
</table>
Section 14: Suspension Systems 575

Chapter 46: Suspension Systems 577
- Introduction 577
- Shock Absorbers and Struts 577
- Ball Joints 582
- Short, Long-Arm (SLA) Front Suspension Systems 583
- MacPherson Strut-Type Front Suspension System Design 585
- Torsion Bar Suspension 587
- Live-Axle Rear Suspension Systems 587
- Semi-Independent Rear Suspension Systems 589
- Independent Rear Suspension Systems 590
- Curb Riding Height 591
- Spring Sag, Curb Riding Height, and Caster Angle 591
- Electronic Air Suspension System 591
- Continuously Variable Road Sensing Suspension (CVRSS) System 595
- Review Questions 597

Chapter 47: Suspension System Maintenance, Diagnosis, and Service 599
- Introduction 599
- Shock Absorber Maintenance 599
- Shock Absorber Diagnosis 600
- Shock Absorber Service 600
- Front and Rear Suspension System Maintenance 604
- Curb Riding Height Measurement 605
- Front and Rear Suspension Diagnosis and Service 605
- Electronic Air Suspension System Maintenance 608
- Electronic Air Suspension Diagnosis 608
- Electronic Air Suspension System Service 609
- Continuously Variable Road Sensing Suspension System (CVRSS) Maintenance 610
- Continuously Variable Road Sensing Suspension System (CVRSS) Diagnosis and Service 611
- Review Questions 614

Section 15: Steering Systems 617

Chapter 48: Supplemental Restraint Systems 619
- Air Bag System Components 619
- Air Bag System Operation 622
- Multi-Stage Air Bag Deployment 623
- Side Impact Air Bags 624
- Smart Air Bag Systems 624
- Seat Belt Pretensioners 624
- Supplemental Restraint System Maintenance 625
- Supplemental Restraint System Diagnosis 625
- Air Bag System Service 626
- Review Questions 627

Chapter 49: Steering Columns, Linkages, and Power Steering Pumps, Maintenance, Diagnosis and Service 629
- Introduction 629
- Steering Column Design 629
- Parallelogram Steering Linkages 632
- Rack and Pinion Steering Linkages 634
- Steering Damper 635
- Power Steering Pump Design 636
- Steering Column Maintenance and Diagnosis 637
- Steering Linkage Maintenance and Diagnosis 639
- Steering Linkage Service 640
- Power Steering Pump Maintenance and Diagnosis 642
- Power Steering Pump Service 645
- Review Questions 646

Chapter 50: Manual and Power Steering Gears Maintenance, Diagnosis, and Service 648
- Introduction 648
- Manual Recirculating Ball Steering Gears 648
- Manual Rack-and-Pinion Steering Gears 650
- Power Recirculating Ball Steering Gears 651
- Power Rack-and-Pinion Steering Gears 653
- Electronic Power Steering Systems 656
- Manual Steering Gear Maintenance and Diagnosis 656
- Manual Steering Gear Service 659
- Power Steering Gear Maintenance and Diagnosis 662
- Power Steering Gear Service 666
- Review Questions 670

Index 673