

Trade of Motor Mechanic

Module 2

Unit 5

STARTER MOTOR/CIRCUIT

Produced by

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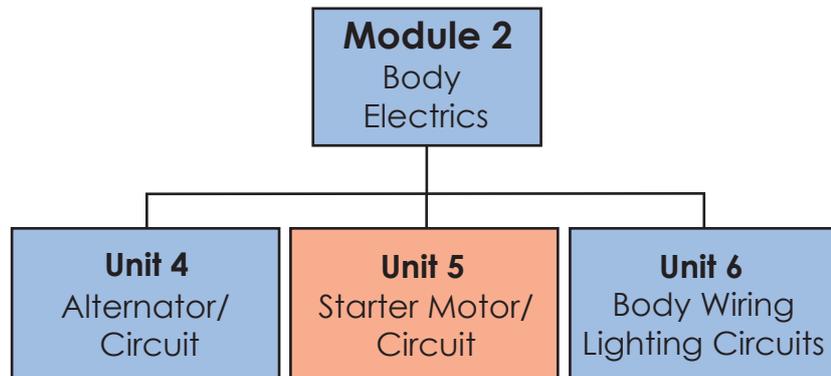
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Introduction

There are six Units in this Module. In Theory 1 we cover Units 1, 2 and 3 which focuses on the basics of electricity. In Theory 2 we cover Units 4, 5 and 6 which focuses on the fundamental electrical circuits in the vehicle.



On completion of this unit you will be able to describe the basic function and operation of the starter/motor circuit. Health and safety issues related to this unit will also be covered in this unit.

Unit Objective

By the end of this unit you will be able to:

- Describe the basic function and operation of the starter/motor circuit
- Describe basic operation of a permanent direct current (DC) motor and a pre-engaged starter motor
- Draw a basic schematic block diagram of the starter circuit and State the average current requirements for the starter motor of a 12V petrol or diesel automobile
- Remove a pre-engaged starter motor, dismantle, examine and report on the condition of the brushes then reassemble and bench test
- Test the starter circuit of an operational vehicle using a multimeter

1.0 Health and Safety

If the proper safety procedures are not adhered when working on *starter motors* this could lead to serious injury to personnel.

Instruction is given in the proper & safe procedures/methods for working and testing Starter Motors include the following:

- Removing and refitting of motors
- Motor free run tests
- Working with live terminals
- Bench run tests
- Rotating pinion
- Arching/voltage peaks – effect on electronic circuits/ component

Refer to motor risk assessments, Environmental policy and Material Safety Data Sheets (MSDS)

2.0 The Permanent Magnet DC Motor

Key Learning Points

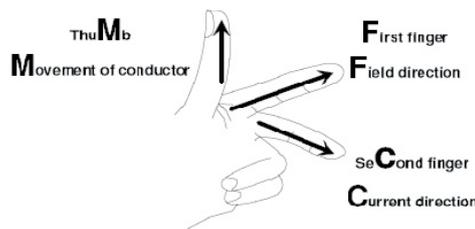
- Electric motor; Fleming's left-hand rule (motor rule) interaction between magnet fields, permanent and armature, purpose of commutation

2.1 Fleming's Left Hand Rule

Also known as the Motor Rule this is a way of determining the direction of a force on a current carrying conductor in a magnetic field.

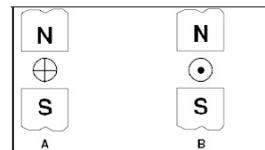
The thumb, the first and second fingers on the left hand are held so that they are at right angles to each other.

If the first finger points in the direction of the magnetic field and the second finger the direction of the current in the wire, then the thumb will point in the direction of the force on the conductor.

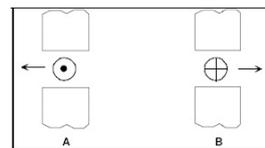


A little practice will show how easy this rule is to apply, but it must be carried out using the left hand and applies only to the motor effect. Examine the diagrams and determine the following:

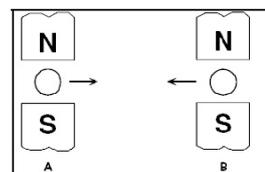
The direction on which the conductor is moved by the magnetic forces.



The polarity of the magnet system.



The direction of the current flow in the conductor.



2.2 Motor Principles (Magnets)

When electric current flows in a conductor it gives rise to a magnetic field, this concept is illustrated in Figure 1a. This current carrying conductor experiences a force which makes it move when it is placed between the poles of a powerful magnet, Figure 1b. The conductor moves because the magnetic field of the permanent magnet reacts with the magnetic field produced by the current in the conductor.

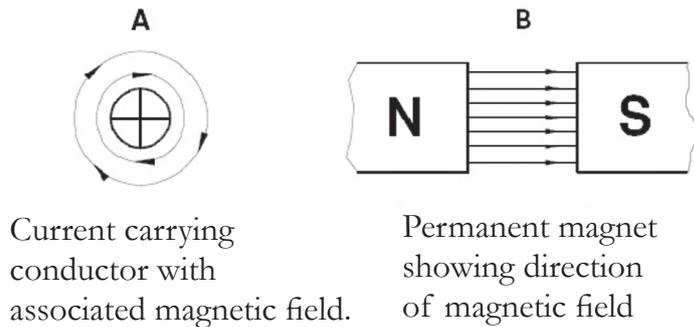


Figure 1a and 1b

Figure 2 illustrates the combined flux of the magnet and the conductor carrying a current. At side A the magnetic field lines of the magnet and the conductor are in the same direction and so reinforce one another. At B the magnetic field lines of the magnet and the conductor are in opposite directions, so they tend to cancel each other out. The result is a sort of ‘catapult’ effect, which propels the conductor in the direction of the arrow.

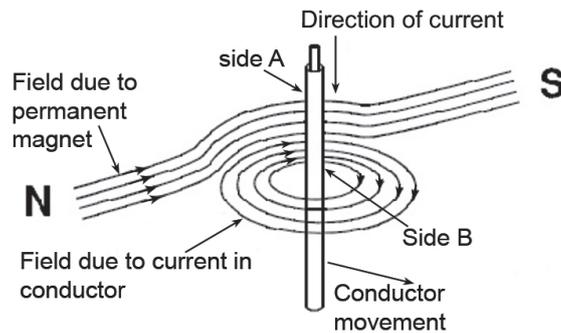
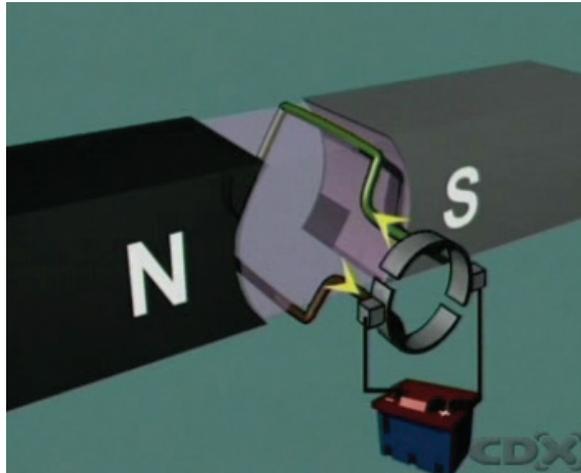


Figure 2

It is often important to know the direction of the force on a conductor when it carries a current of given direction in a magnetic field of given polarity. One method is to draw out the magnetic field as shown above, but there is a rule which links the directions of the current, magnetic field and movement of the conductor and which enables us to find the third unknown if the directions of the other two are known.

2.3 Commutation



When current flows in a conductor, an electromagnetic field is generated around it. If the conductor is placed so that it cuts across a stationary magnetic field, the conductor will be forced out of the stationary field. This happens because the lines of force of the stationary field are distorted by the electro-magnetic field around the conductor and try to return to a straight line condition.

Reversing the direction of current flow in the conductor will cause the conductor to move in the opposite direction. This is known as the motor effect and is greatest when the current carrying conductor and the stationary magnetic field are at right angles to each other.

A conductor loop which can freely rotate within the magnetic field is the most efficient design. In this position, when current flows through the loop the stationary magnetic field is distorted and the lines of force try to straighten. This forces one side of the loop up and the other side of the loop down. The motor effect causes the loop to rotate until it is at ninety degrees to the magnetic field. To continue rotation, the direction of current flow in the conductor must be reversed at this static neutral point. A commutator is used for this purpose.

An example commutator consists of two semi-circular segments which are connected to the two ends of the loop and are insulated from each other. Carbon impregnated brushes provide a sliding connection to the commutator to complete the circuit and allow current to flow through the loop. Rotation commences with both sides of the conductor loop cutting the stationary field. When the loop passes the point where the field is no longer being cut, the momentum of rotation carries the loop and the commutator segments over so that the brushes maintain current flow in the same direction in each side of the loop relative to the stationary field.

This process will maintain a consistent direction of rotation of the loop. In order to achieve a uniform motion and torque output, the number of loops must be increased. The additional loops smooth out the rotational forces.

A starter motor armature has a large number of conductor loops and so has many segments on the commutator.

3.0 The Pre-Engaged Starter Motor

Key Learning Points

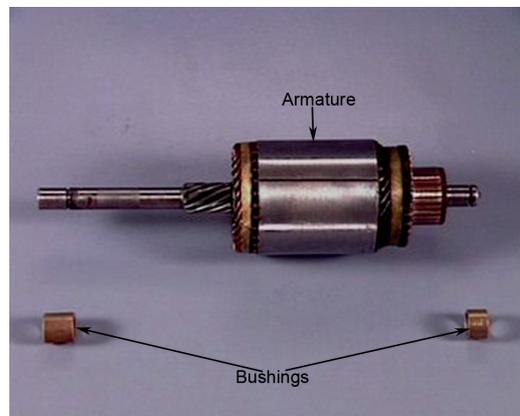
- Electric motor; converts electrical energy into mechanical energy
- Starter motor function; crank engine over at suitable starting speeds at different temperatures, effects of current/excessive current draws on battery voltage

3.1 Basic Function

The starter motor converts electrical energy to mechanical energy. It is mounted on the cylinder block in a position to engage a ring gear on the engine flywheel. The starter motor is powered by the battery. It is designed to have high turning effort at low speeds. During engine cranking excessive current draw will lead to the cables becoming hot and a drop in battery voltage.

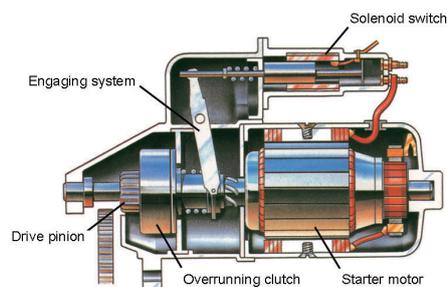
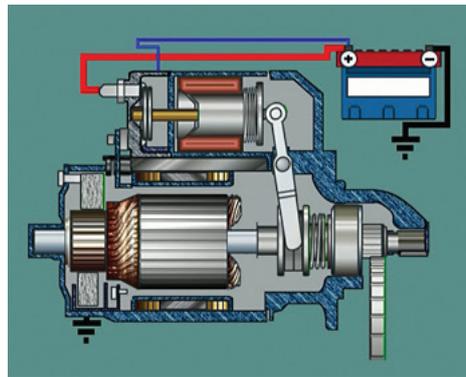
3.2 Starter Motor Principles

A direct-current (DC) motor is a device for converting dc electrical energy into rotating mechanical energy. All motors have several basic characteristics in common. They include: A stator, which is the frame and other stationary components (provides the fixed magnetic field, could be a permanent magnet or an electromagnet); a rotor or armature, which is the rotating shaft and its associated parts (many coils of wire are wound on a cylindrical shaft); auxiliary equipment, such as a brush/commutator assembly for DC motors and a starting circuit for AC motors.



3.3 Basic Operation

The starter motor is a necessity for internal-combustion engines, because the Otto cycle requires the pistons already to be in motion before the ignition phase of the cycle. This means that the engine must be started in motion by an outside force, before it can power itself.



Courtesy of Volkswagen

The modern starter motor is an electric motor with a solenoid switch, similar to a relay, bolted to its side. When low-current power from the lead-acid battery is applied to the solenoid, usually through a key switch, it pulls out a small pinion gear on the starter motor's shaft and meshes it with the ring gear on the flywheel of the engine. The solenoid also closes high-current contacts for the starter motor and it starts to run. If the engine starts the key switch is released, the solenoid pulls the small gear back off the starter gear and the starter motor stops running. Modern starter motors have a special Bendix gear and freewheel that enables the flywheel to automatically disengage the pinion gear from the flywheel when the engine starts.

The starter cables are the thickest on the vehicle, as a high current must be delivered to the starter motor, to turn the crankshaft from rest and keep it turning until the engine fires and runs on its own.

4.0 Basic Schematic Block Diagram

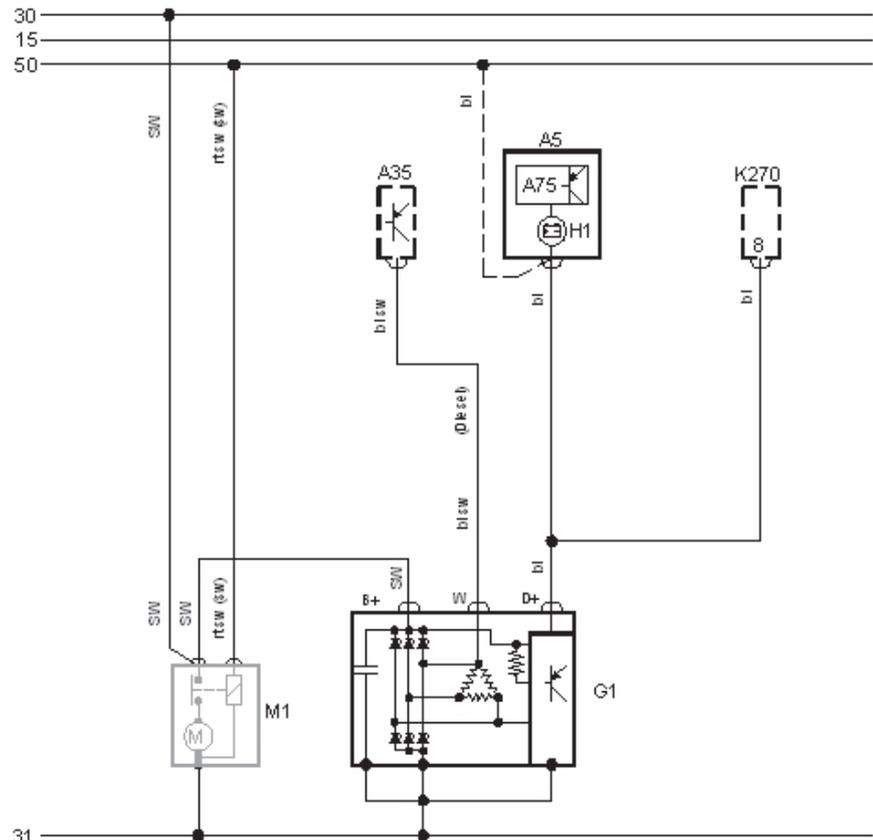
Key Learning Points

- The drawing/interpreting basic schematic starter circuit wiring Diagram
- Terminal designations 30, 31, 15, 50

4.1 Basic Schematic Diagram

See the following page.

Alternator/Starter Motor-Wiring Circuit



Manufacturer:

Volkswagen

Engine code:

AFN

Tuned for:

Model: Passat
(96-00) D TDI
Output: 81 (110)
4150

Year: 1996-00

*Reproduced courtesy
of Autodata
Limited, unit
5 priors way,
maidenhead,
England.*

Component

- G1** Alternator
- H1** Alternator warning lamp
- 31** Battery -
- 30** Batter +
- A35** Engine control module
- K270** Engine running circuits relay
- 15** Ignition switch - ignition ON
- 50** Ignition switch - start signal
- A35** Instrument panel
- A75** Instrumentation control module
- M1** Starter motor

Wiring colour Codes

- bl blue
- gn green
- rs pink
- ws white
- x braided cable
- br brown
- gr grey
- rt red
- hbl light blue
- y high tension
- el cream
- nf neutral
- sw black
- hgn light green
- z non-cable connection
- ge yellow
- og orange
- vi violet
- rbr maroon

Refer to Automotive technical manuals for these diagrams

Starter System DIN Numbers

DIN72552 Electric terminal numbers

Automobile Electric Terminal Numbers According to DIN 72552

For almost every contact in a car there is a number code to standardize car wiring. These numbers are defined in DIN 72552. This table gives most frequently used numbers for starter systems.

<i>Contact ID</i>	<i>Identification</i>
15	Battery+ through ignition switch
30	From battery+ direct
50	Starter control
31	Return to battery – or direct to ground

5.0 Current Requirements of a 12V Starter Motor

Key Learning Points

- Current requirements of petrol/diesel engines and the effect of ambient temperature change

5.1 Current Requirements

Current requirements differ between petrol and diesel engines. This is because of the different compression ratios also the ambient temperature has an effect on the amount of current draw especially on the diesel engine as it may require the use of heater plugs.

Additional information, is available from the automotive technical manuals.

6.0 To Examine and Refit a Starter Motor

Key Learning Points

- Removal and refitting of motor care with permanent live leads, brushes examined for serviceability, motor free run test. No arcing of live terminals, motor securely located for bench run test, danger of movement and rotating pinion. Damage to vehicle electronic circuit components by arcing/voltage peaks.

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals. Please observe safety instructions in the Key Learning Points.

7.0 Testing a Starter Motor Using a Multimeter.

Key Learning Points

- Use of a multimeter to evaluate voltage drop/loss on connecting cables/straps/permanent connections, results compared and interpreted to manufacturer's recommended tolerances

Practical Task *This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.*

Checking a Starting System

Preparation and Safety

Objective Check a starting system.



Personal Safety Whenever you perform a task in the workshop you must use personal protective clothing and equipment that is appropriate for the task and which conforms to your local safety regulations and policies. Among other items, this may include:

- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

Safety Check

- Make sure the bonnet rod is secure.
- Always make sure that you wear the appropriate personal protection equipment before starting the job. It is very easy to hurt yourself even when the most exhaustive protection measures are taken.
- Always ensure that your work area/environment is as safe as you can make it. Do not use damaged, broken or worn out workshop equipment.
- Always follow any manufacturer's personal safety instructions to prevent damage to the vehicle you are servicing.
- Make sure that you understand and observe all legislative and personal safety procedures when carrying out the following tasks. If you are unsure of what these are, ask your instructor.

Points to Note

DVOMs come in many forms. Always follow the specific manufacturer's instructions in the use of the meter or you could seriously damage the meter or electrical circuit.

Step-by-Step Instruction

1. *Set up the meter for a voltage check:* Prepare the Digital Volt Ohm Meter or DVOM for testing for voltage by inserting the black probe lead into the “common” input port and the red probe lead into the “Volt/Ohms” input port.
2. *Check the meter function:* Turn the rotary dial until you have selected the mode for “Volts DC”. The reading on the meter should now be at Zero. Some meters will automatically sense the correct voltage range for the meter when a voltage is detected. On other meters you will have to set the voltage range before using the meter.
3. *Check the battery voltage:* Place the Black probe onto the Negative terminal of the battery, which will be marked with a Minus sign and place the Red probe onto the Positive terminal of the battery. This is marked with a Plus sign. Note the voltage reading from the battery.

4. *Disconnect the ignition system:* With the meter still connected to the battery, disconnect the ignition system. Refer to manufactures instructions at all times. Usually, simply disconnecting the coil lead, or alternatively, disconnecting the spark plug leads, will ensure the vehicle will not start when you turn the engine over with the starter motor, which is known as ‘cranking’ the engine. Choose a method suitable for the type of ignition system in the vehicle you are working on. In most modern vehicles, it is better to allow the ignition spark generated by cranking the engine to have some safe alternative place to go.
5. *Crank the engine and check result:* Crank the engine whilst at the same time watching the voltage displayed on the DVOM. This test checks the starter circuit for voltage drop and gives a good indication of the condition of the starter circuit voltage. If the reading remains above 10.25 Volts then the system is in good condition. If the reading is below 10.25 Volts then this may indicate a fault with the starting system and further investigation is required.
6. *Starter motor electrical connections:* If the required voltage is present at the solenoid motor terminal, any problem may be in the starter motor or its cabling. If the original test indicated normal voltage, but slow or no cranking, check the motor system and its connections. If the drive pinion keeps shifting out of mesh with the flywheel, check for a broken or a loose external ground wire on the solenoid. Replace a broken wire or re-attach a loose one. Place an ammeter in the circuit to measure the amp in either the positive, or ground cable of the starter motor. With the ammeter in place, press the start switch. If the amp draw is excessive, according to the manufacturer’s specifications, then the starter motor is probably faulty. Before you replace the starter, check the condition of the engine to make sure it turns freely. An engine in poor condition could cause the starter to work harder and may have been damaged by the engine’s poor condition.

Self Assessment

Q1: The overrunning clutch in the pinion ensures the armature does not? (Tick one box only)

- 1. Over heat if the engine does not start
- 2. Commence turning before the pinion engages
- 3. Stops turning when the engine starts
- 4. Over speed when the engine starts

Q2: When activated the starter solenoid: (Tick one box only)

- 1. Engages the pinion
- 2. Switches current to the motor
- 3. Engages the pinion and switches current to the motor
- 4. None of these actions

Q3: In the starter motor switching mechanism there are two windings with different resistance values. Which of the two has a low resistance value? (Tick one box only)

- 1. The hold in winding
- 2. The armature winding
- 3. The field winding
- 4. The pull in winding

Q4: It is desirable for a starter motor to produce: (Tick one box only)

- 1. Low turning effort at low speeds
- 2. Low turning effort at high speeds
- 3. High turning effort at high speeds
- 4. High turning effort at low speeds

Q5: The alternator converts: (Tick one box only)

- 1. Mechanical energy into electrical energy
- 2. Mechanical energy into chemical energy
- 3. Electrical energy into chemical energy
- 4. Electrical energy into mechanical energy

Q6: The starter motor converts: (Tick one box only)

- 1. Electrical energy into mechanical energy
- 2. Mechanical energy into chemical energy
- 3. Electrical energy into chemical energy
- 4. Mechanical energy into electrical energy

Task Sheets

Preparation and Safety

Objective

Check a starting system.



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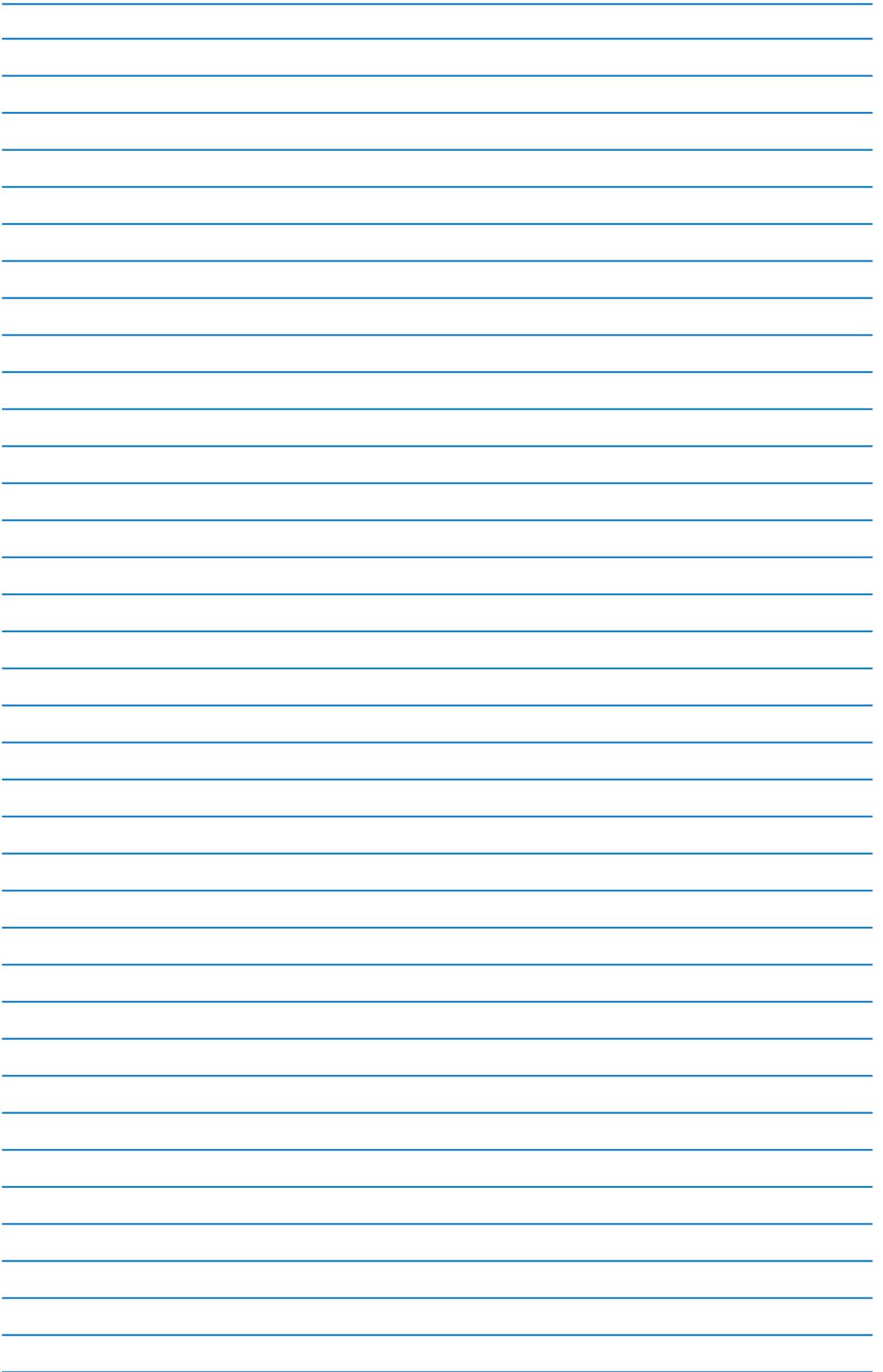
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Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- <http://www.cdxglobal.com/>
- <http://auto.howstuffworks.com/>
- <http://www.autoshop101.com/>
- <http://www.cdxetextbook.com/>
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.



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