

BMW

5 Series

(E39)



Service Manual
525i, 528i, 530i, 540i
Sedan, Sport Wagon
1997, 1998, 1999, 2000, 2001, 2002



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WARNING—important safety notice

Do not use this manual unless you are familiar with basic automotive repair procedures and safe workshop practices. This manual illustrates the workshop procedures required for most service work. It is not a substitute for full and up-to-date information from the vehicle manufacturer or for proper training as an automotive technician. Note that it is not possible for us to anticipate all of the ways or conditions under which vehicles may be serviced or to provide cautions as to all of the possible hazards that may result.

The vehicle manufacturer will continue to issue service information updates and parts retrofits after the editorial closing of this manual. Some of these updates and retrofits will apply to procedures and specifications in this manual. We regret that we cannot supply updates to purchasers of this manual.

We have endeavored to ensure the accuracy of the information in this manual. Please note, however, that considering the vast quantity and the complexity of the service information involved, we cannot warrant the accuracy or completeness of the information contained in this manual.

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Your common sense and good judgment are crucial to safe and successful service work. Read procedures through before starting them. Think about whether the condition of your car, your level of mechanical skill, or your level of reading comprehension might result in or contribute in some way to an occurrence which might cause you injury, damage your car, or result in an unsafe repair. If you have doubts for these or other reasons about your ability to perform safe repair work on your car, have the work done at an authorized BMW dealer or other qualified shop.

Part numbers listed in this manual are for identification purposes only, not for ordering. Always check with your authorized BMW dealer to verify part numbers and availability before beginning service work that may require new parts.

Before attempting any work on your BMW, read the 001 General Warnings and Cautions, and any WARNING or CAUTION that accompanies a procedure in the service manual. Review the WARNINGS and CAUTIONS each time you prepare to work on your BMW.

Special tools required to perform certain service operations are identified in the manual and are recommended for use. Use of tools other than those recommended in this service manual may be detrimental to the car's safe operation as well as the safety of the person servicing the car.

Copies of this manual may be purchased from most automotive accessories and parts dealers specializing in BMW automobiles, from selected booksellers, or directly from the publisher.

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Automotive Reference

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Foreword

For the BMW owner with basic mechanical skills and for independent auto service professionals, this manual includes many of the specifications and procedures that were available to an authorized BMW dealer service department as this manual went to press. The BMW owner with no intention of working on his or her car will find that owning and referring to this manual makes it possible to be better informed and to more knowledgeably discuss repairs with a professional automotive technician.

If you are a BMW owner intending to do maintenance and repair work, make sure you have screwdrivers, a set of metric wrenches and sockets and metric Allen and Torx wrenches, since these basic hand tools are needed for most of the work described in this manual. Many procedures also require a torque wrench to ensure that fasteners are tightened properly and in accordance with specifications. Additional information on basic tools and other tips are in **010 General**. In some cases, the text refers to special tools that are recommended or required to accomplish adjustments or repairs. These tools are usually identified by their BMW special tool number and illustrated.

Disclaimer

We have endeavored to ensure the accuracy of the information in this manual. When the vast array of data presented in the manual is taken into account, however, no claim to infallibility can be made. We therefore cannot be responsible for the result of any errors that may have crept into the text. Please also read the **Important Safety Notice** on the copyright page at the beginning of this book.

Prior to starting a repair procedure, read the procedure, **001 General Warnings and Cautions** and the warnings and cautions that accompany the procedure. Reading a procedure before beginning work will help you determine in advance the need for specific skills, identify hazards, prepare for appropriate capture and handling of hazardous materials, and the need for particular tools and replacement parts such as gaskets.

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BMW offers extensive warranties, especially on components of the fuel delivery and emission control systems. Therefore, before deciding to repair a BMW that may be covered wholly or in part by any warranties issued by BMW of North America, LLC, consult your authorized BMW dealer. You may find that the dealer can make the repair either free or at minimum cost. Regardless of its age, or whether it is under warranty, your BMW is both an easy car to service and an easy car to get serviced. So if at any time a repair is needed that you feel is too difficult to do yourself, a trained BMW technician is ready to do the job for you.

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001 General Warnings and Cautions

**PLEASE READ THESE WARNINGS AND CAUTIONS
BEFORE PROCEEDING WITH MAINTENANCE AND REPAIR WORK.**

WARNINGS—

See also **CAUTIONS**

- Some repairs may be beyond your capability. If you lack the skills, tools and equipment, or a suitable workplace for any procedure described in this manual, we suggest you leave such repairs to an authorized BMW dealer service department or other qualified shop.
- Do not reuse any fasteners that are worn or deformed. Many fasteners are designed to be used only once and become unreliable and may fail when used a second time. This includes, but is not limited to, nuts, bolts, washers, self-locking nuts or bolts, circlips and cotter pins. Always replace these fasteners with new parts.
- Never work under a lifted car unless it is solidly supported on stands designed for the purpose. Do not support a car on cinder blocks, hollow tiles or other props that may crumble under continuous load. Never work under a car that is supported solely by a jack. Never work under the car while the engine is running.
- If you are going to work under a car on the ground, make sure that the ground is level. Block the wheels to keep the car from rolling. Disconnect the battery negative (-) terminal to prevent others from starting the car while you are under it.
- Never run the engine unless the work area is well ventilated. Carbon monoxide kills.
- Rings, bracelets and other jewelry should be removed so that they cannot cause electrical shorts, get caught in running machinery, or be crushed by heavy parts.
- Tie long hair behind your head. Do not wear a necktie, a scarf, loose clothing, or a necklace when you work near machine tools or running engines. If your hair, clothing, or jewelry were to get caught in the machinery, severe injury could result.
- Do not attempt to work on your car if you do not feel well. You increase the danger of injury to yourself and others if you are tired, upset or have taken medication or any other substance that may keep you from being fully alert.
- Illuminate your work area adequately but safely. Use a portable safety light for working inside or under the car. Make sure the bulb is enclosed by a wire cage. The hot filament of an accidentally broken bulb can ignite spilled fuel, vapors or oil.
- Catch draining fuel, oil, or brake fluid in suitable containers. Do not use food or beverage containers that might mislead someone into drinking from them. Store flammable fluids away from fire hazards. Wipe up spills at once, but do not store the oily rags, which can ignite and burn spontaneously.
- Always observe good workshop practices. Wear goggles when you operate machine tools or work with battery acid. Gloves or other protective clothing should be worn whenever the job requires working with harmful substances.
- Greases, lubricants and other automotive chemicals contain toxic substances, many of which are absorbed directly through the skin. Read the manufacturer's instructions and warnings carefully. Use hand and eye protection. Avoid direct skin contact.
- Disconnect the battery negative (-) terminal whenever you work on the fuel system or the electrical system. Do not smoke or work near heaters or other fire hazards. Keep an approved fire extinguisher handy.
- Friction materials (such as brake pads or shoes or clutch discs) contain asbestos fibers or other friction materials. Do not create dust by grinding, sanding, or by cleaning with compressed air. Avoid breathing dust. Breathing any friction material dust can lead to serious diseases and may result in death.
- Batteries give off explosive hydrogen gas during charging. Keep sparks, lighted matches and open flame away from the top of the battery. If hydrogen gas escaping from the cap vents is ignited, it will ignite gas trapped in the cells and cause the battery to explode.
- Connect and disconnect battery cables, jumper cables or a battery charger only with the ignition switched off. Do not disconnect the battery while the engine is running.
- Do not quick-charge the battery (for boost starting) for longer than one minute. Wait at least one minute before boosting the battery a second time.
- Do not allow battery charging voltage to exceed 16.5 volts. If the battery begins producing gas or boiling violently, reduce the charging rate. Boosting a sulfated battery at a high charging rate can cause an explosion.

Continued on next page

General Warnings and Cautions

WARNINGS (continued)

- The air conditioning system is filled with chemical refrigerant, which is hazardous. The A/C system should be serviced only by *trained technicians using approved refrigerant recovery/recycling equipment, trained in related safety precautions, and familiar with regulations governing the discharging and disposal of automotive chemical refrigerants.*
- Do not expose any part of the A/C system to high temperatures such as open flame. Excessive heat will increase system pressure and may cause the system to burst.
- Some aerosol tire inflators are highly flammable. Be extremely cautious when repairing a tire that may have been inflated using an aerosol tire inflator. Keep sparks, open flame or other sources of ignition away from the tire repair area. Inflate and deflate the tire at least four times before breaking the bead from the rim. Completely remove the tire from the rim before attempting any repair.
- Cars covered by this manual are equipped with a supplemental restraint system (SRS), that automatically deploys airbags and pyrotechnic seat belt tensioners in the event of a frontal or side impact. These are explosive devices. Handled improperly or without adequate safeguards, they can be accidentally activated and cause serious injury.
- The ignition system produces high voltages that can be fatal. Avoid contact with exposed terminals and use extreme care when working on a car with the engine running or the ignition switched on.
- Place jack stands only at locations specified by the manufacturer. The vehicle lifting jack supplied with the vehicle is intended for tire changes only. A heavy duty floor jack should be used to lift vehicle before installing jack stands. See **010 General**.
- Battery acid (electrolyte) can cause severe burns. Flush contact area with water, seek medical attention.
- Aerosol cleaners and solvents may contain hazardous or deadly vapors and are highly flammable. Use only in a well ventilated area. Do not use on hot surfaces (engines, brakes, etc.).
- Do not remove coolant reservoir or radiator cap with the engine hot. Danger of burns and engine damage.
- Before starting a job, make certain that you have all the necessary tools and parts on hand. Read all the instructions thoroughly, and do not attempt shortcuts. Use tools appropriate to the work and use only replacement parts meeting BMW specifications.
- Use pneumatic and electric tools only to loosen threaded parts and fasteners. Never use these tools to tighten fasteners, especially on light alloy parts. Always use a torque wrench to tighten fasteners to the tightening torque specification listed.
- Be mindful of the environment and ecology. Before you drain the crankcase, find out the proper way to dispose of the oil. Do not pour oil onto the ground, down a drain, or into a stream, pond or lake. Dispose of waste in accordance with Federal, State and Local laws.
- The control module for the anti-lock brake system (ABS) cannot withstand temperatures from a paint-drying booth or a heat lamp in excess of 203° F (95° C) and should not be subjected to temperatures in excess of 185° F (85° C) for more than two hours.
- Before doing any electrical welding on cars equipped with ABS, disconnect the battery negative (-) terminal (ground strap) and the ABS control module connector.
- Always make sure ignition is off before disconnecting battery.
- Label battery cables before disconnecting. On some models, battery cables are not color coded.
- Disconnecting the battery may erase fault code(s) stored in control module memory. Using special BMW diagnostic equipment, check for fault codes prior to disconnecting the battery cables. If the malfunction indicator light (MIL) is illuminated, see **OBD On-Board Diagnostics**. This light is identified as the Check Engine light (1997-2000 models) or Service Engine Soon light (2001 and later models). If any other system faults have been detected (indicated by an illuminated warning light), see an authorized BMW dealer.
- If a normal or rapid charger is used to charge battery, the battery must be disconnected and removed from the vehicle in order to avoid damaging the vehicle.
- Do not quick-charge the battery (for boost starting) for longer than one minute. Wait at least one minute before boosting the battery a second time.
- Connect and disconnect a battery charger only with the battery charger switched off.
- Sealed or "maintenance free" batteries should be slow-charged only, at an amperage rate that is approximately 10% of the battery's ampere-hour (Ah) rating.
- Do not allow battery charging voltage to exceed 16.5 volts. If the battery begins producing gas or boiling violently, reduce the charging rate. Boosting a sulfated battery at a high charging rate can cause an explosion.

CAUTIONS—

See also **WARNINGS**

- If you lack the skills, tools and equipment, or a suitable workshop for any procedure described in this manual, leave such repairs to an authorized BMW dealer or other qualified shop.
- BMW is constantly improving its cars and sometimes these changes, both in parts and specifications, are made applicable to earlier models. Therefore, part numbers listed in this manual are for reference only. Always check with your authorized BMW dealer parts department for the latest information.



002 Vehicle Identification and VIN Decoder

Vehicle Identification Number (VIN), decoding

Some of the information in this manual applies only to cars of a particular model year or range of years. For example, 1999 refers to the 1999 model year but does not necessarily match the calendar year in which the car was manufactured or sold. To be sure of the model year of a particular car, check the Vehicle Identification Number (VIN) on the car.

The VIN is a unique sequence of 17 characters assigned by BMW to identify each individual car. When decoded, the VIN tells the country and year of manufacture; make, model and serial number; assembly plant and some equipment specifications.

The BMW VIN is on a plate mounted on top of the dashboard, on the driver's side where the number can be seen through the windshield. The 10th character is the model year code. The letters I, O, Q and U are not used for model year designation. Examples: X for 1999, Y for 2000, 1 for 2001, 2 for 2002, etc. The table below explains some of the codes in the VIN for 1997 through 2002 BMW E39 5 Series BMWs covered by this manual.

Sample VIN: **WBA DE63 20WB W61389**
 position 1 2 3 4 5 6 7 8 9 10 11 12-17

VIN position	Description	Decoding information	
1 - 3	Country of manufacture	WBA WBS	BMW, AG. Munich, Germany BMW Motorsport, GmbH, Munich, Germany
4	Line	D	525i (2001 - 2003) 528i (2000-2003), 530i, 540i
5	Series	D E J M N P R T	525i (2001 - 2002), 528i (1997 - 2000) M5, 530i, 540i (1997 - 1998) 525i Wagon 528i (1999 - 2000) 540i Sedan (1999 - 2003) 540i wagon (2001) 528i wagon (1999 - 2000) 540i wagon (2002 - 2003) 525i sedan (2002 - 2003), 530i (2001 - 2003)
6	Body type / engine type	6,4 5,3	Automatic Manual
7	Vehicle type	3, 4, 7	Passenger vehicle
8	Restraint system	0 1 2 3 4	Manual belts Manual belts with dual airbags Manual belts with advanced airbags Manual belts with driver & passenger airbags Manual belts with advanced passenger & driver airbags
9	Check digit		0 - 9 or X, calculated by NHTSA
10	Model year	V W X Y 1 2 3	1997 1998 1999 2000 2001 2002 2003
11	Assembly plant	A, F, K B, C, D, G E, J, P	Munich, Germany Dingolfing, Germany Regensburg, Germany
12-17	Serial number		Sequential production number for specific vehicle

010 General

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GENERAL

This section is intended to help the do-it-yourselfer get started. Tips on workshop practices, basic tools, and a quick reference guide to emergencies can be found here.

WARNING—

- *Do not use this manual unless you are familiar with basic automotive repair procedures and safe workshop practices.*
- *This manual illustrates the workshop procedures required for most service work; it is not a substitute for full and up-to-date information from the vehicle manufacturer or for proper training as an automotive technician.*
- *Note that it is not possible to anticipate all of the ways or conditions under which vehicles may be serviced or to provide cautions as to all of the possible hazards that may result.*

HOW TO USE THIS MANUAL

WARNING—

Your common sense and good judgement are crucial to safe and successful service work. Read procedures through before starting them. Think about whether the condition of your car, your level of mechanical skill, or your level of reading comprehension might result in or contribute in some way to an occurrence that might cause you injury, damage your car, or result in an unsafe repair. If you have doubts for these or other reasons about your ability to perform safe repair work on your car, have the work done at an authorized BMW dealer or other qualified shop.

The manual is divided into ten sections:

- 0 GENERAL, MAINTENANCE
- 1 ENGINE
- 2 TRANSMISSION
- 3 SUSPENSION, STEERING AND BRAKES
- 4 BODY
- 5 BODY EQUIPMENT
- 6 ELECTRICAL SYSTEM
- 7 EQUIPMENT AND ACCESSORIES
- ELE ELECTRICAL WIRING DIAGRAMS
- OBD ON-BOARD DIAGNOSTICS

0 GENERAL, MAINTENANCE covers general vehicle information (**010 General**) as well as the recommended maintenance schedules and service procedures to perform BMW scheduled maintenance work (**020 Maintenance**).

The next seven sections (1 through 7) are repair based and organized by three digit repair groups. Most major sections begin with a GENERAL repair group, e.g. **100 Engine-General**. These "00" (double zero) groups contain descriptive theory of operation and system troubleshooting information. The remainder of the repair groups within a section contain the service and repair information. The last two sections contain detailed electrical wiring schematics and OBD II scan tool and diagnostic information.

Warnings, cautions and notes

Throughout this manual are many passages with the headings WARNING, CAUTION, or NOTE. These very important headings have different meanings.

WARNING—

The text under this heading warns of unsafe practices that are very likely to cause injury, either by direct threat to the person(s) performing the work or by increased risk of accident or mechanical failure while driving.

CAUTION—

A CAUTION calls attention to important precautions to be observed during the repair work that will help prevent accidentally damaging the car or its parts.

NOTE—

A NOTE contains helpful information, tips that will help in doing a better job and completing it more easily.

Please read every WARNING, CAUTION, AND NOTE in **001 General Warnings and Cautions** and as they appear in repair procedures. They are very important. Read them before you begin any maintenance or repair job.

WARNING—

- *Never run the engine in the work area unless it is well-ventilated. The exhaust should be vented to the outside. Carbon monoxide (CO) in exhaust kills.*
- *Remove all neckties, scarfs, loose clothing, or jewelry when working near a running engine or power tools. Tuck in shirts. Tie long hair and secure it under a cap. Severe injury can result from these things being caught in rotating parts.*
- *Remove rings, watches, and bracelets. Aside from the dangers of moving parts, metallic jewelry conducts electricity and may cause shorts, sparks, burns, or damage to the electrical system when accidentally contacting the battery or other electrical terminals.*
- *Disconnect the battery negative (-) cable whenever working on or near the fuel system or anything that is electrically powered. Accidental electrical contact may damage the electrical system or cause a fire.*
- *Fuel is highly flammable. When working around fuel, do not smoke or work near heaters or other fire hazards. Keep an approved fire extinguisher handy.*
- *The fuel system is designed to retain pressure even when the ignition is off. When working with the fuel system, loosen the fuel lines slowly to allow the residual pressure to dissipate gradually. Take precautions to avoid spraying fuel.*
- *Illuminate the work area adequately and safely. Use a portable safety light for working inside or under the car. A fluorescent type light is best because it gives off less heat. If using a light with a normal incandescent bulb, use rough service bulbs to avoid breakage. The hot filament of an accidentally broken bulb can ignite spilled fuel or oil.*
- *Keep sparks, lighted matches, and any open flame away from the top of the battery. Hydrogen gas emitted by the battery is highly flammable. Any nearby source of ignition may cause the battery to explode.*
- *Never lay tools or parts in the engine compartment or on top of the battery. They may fall into confined spaces and be difficult to retrieve, become caught in belts or other rotating parts when the engine is started, or cause electrical shorts and damage to the electrical system.*

GETTING STARTED

Much of the necessary maintenance and minor repair that an automobile will need can be done with ordinary tools. Below you'll find important information on how to work safely, a discussion of what tools will be needed and how to use them.

Safety

Although an automobile presents many hazards, common sense and good equipment can help ensure safety. Many accidents happen because of carelessness. Pay attention and stick to the safety rules in this manual.

Lifting the car

- ◀ The proper jacking points should be used to raise the car safely and avoid damage. The jack supplied with the car can only be used at the four side points (arrows) just behind the front wheels or just in front of the rear wheels.

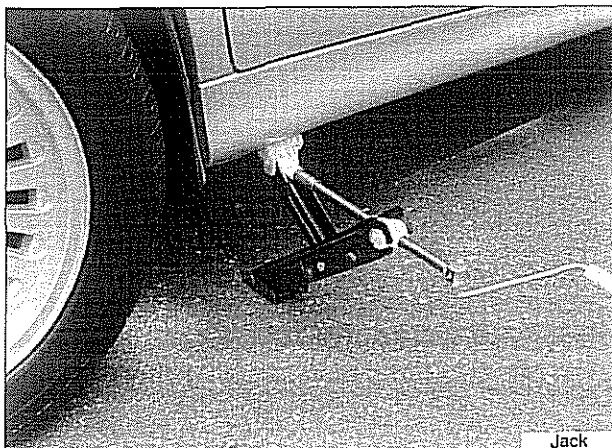


WARNING—

- *Never work under a lifted car unless it is solidly supported on jack stands that are intended for that purpose.*
- *When raising the car using a floor jack or hydraulic lift, carefully position the jack pad to prevent damaging the car body.*
- *Watch the jack closely. Make sure it stays stable and does not shift or tilt. As the car is raised, it may roll slightly and the jack may shift.*

Raising car

- Park car on flat, level surface.
- If changing a tire, loosen lug bolts before raising car. See **Changing a tire.**
- ◀ Place jack into position. Make sure jack is resting on flat, solid surface. Use a board or other support to provide a firm surface for jack, if necessary.
- Raise car slowly while constantly checking position of jack and car.
- Once car is raised, block wheel that is opposite and farthest from jack to prevent car from unexpectedly rolling.



WARNING—

- Do not rely on the transmission or the parking brake to keep the car from rolling. They are not a substitute for positively blocking the opposite wheel.
- Never work under a car that is supported only by a jack. Use jack stands designed to support the car. See **Tools**.

Working under car

- Disconnect negative (-) cable from battery so that car cannot be started. Let others know what you will be doing.

CAUTION—

Prior to disconnecting the battery, read the battery disconnection cautions given in **001 General Cautions and Warnings**.

- Raise car slowly as described above.
- Use at least two jack stands to support car. Use jack stands designed for the purpose of supporting a car. See **Tools**.

WARNING—

- A jack is a temporary lifting device and should not be used alone to support the car while you are under it.
- Do not use wood, concrete blocks, or bricks to support a car. Wood may split. Blocks and bricks, while strong, are not designed for that kind of load, and may break or collapse.

- Place jack stands on firm, solid surface. If necessary, use a flat board or similar solid object to provide a firm footing.
- Lower car slowly until its weight is fully supported by jack stands. Watch to make sure that the jack stands do not tip or lean as the car settles on them.
- Observe all jacking precautions again when raising car to remove jack stands.

ADVICE FOR THE BEGINNER

The tips that follow are general advice to help the do-it-yourself BMW owner perform repairs and maintenance tasks more easily and more professionally.

Planning ahead

Know what the whole job requires before starting. Read the procedure thoroughly, from beginning to end, in order to know just what to expect and what parts will have to be replaced.

Workshop practices

Keeping things organized, neat, and clean is essential to doing a good job. When working under the hood, fender covers will protect the finish from scratches and other damage. Make sure the car finish is clean so that dirt under the cover does not scratch the finish.

Any repair job will be less troublesome if the parts are clean. For cleaning old parts, there are many solvents and parts cleaners commercially available.

For cleaning parts prior to assembly, commercially available aerosol cans of parts cleaner or brake cleaner are handy to use, and the cleaner will evaporate completely.

WARNING —

Most solvents used for cleaning parts are highly flammable as well as toxic, especially in aerosol form. Use with extreme care. Do not smoke. Do not use these products indoors or near any source of heat, sparks or flame.

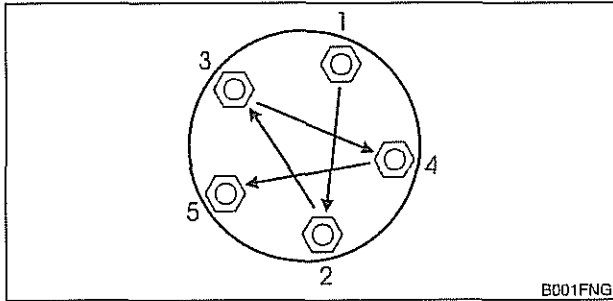
Non reusable fasteners

Many fasteners used on the cars covered by this manual must be replaced with new ones once they are removed. These include but are not limited to: bolts, nuts (self-locking, nylock, etc.), roll pins, clips and washers. Genuine BMW parts should be the only replacement parts used for this purpose.

Some bolts are designed to stretch during assembly and are permanently altered, rendering them unreliable once removed. These are known as torque-to-yield fasteners. Always replace fasteners where instructed to do so. Failure to replace these fasteners could cause personal injury or vehicle damage. See an authorized BMW dealer for applications and ordering information.

Tightening fasteners

When tightening the bolts or nuts on a component, it is always good practice to tighten the bolts gradually and evenly to avoid misalignment or over-stressing any one portion of the component. For components sealed with gaskets, this method helps to ensure that the gasket will seal properly.



- Where there are several fasteners, tighten them in a sequence alternating between opposite sides of the component. Repeat the sequence until all the bolts are evenly tightened to the proper specification.

For some repairs a specific tightening sequence is necessary, or particular order of assembly is required. Such special conditions are noted in the text, and the necessary sequence is described or illustrated. Where no specific torque is listed, **Table a: General bolt tightening torques in Nm (max. permissible)** can be used as a general guide for tightening fasteners.

WARNING —

Table a: General bolt tightening torques in Nm (max. permissible) is a general reference only. The values listed in the table are not intended to be used as a substitute for torques specifically called out in the text or in manufacturer's information.

NOTE —

- Metric bolt classes or grades are marked on the bolt head.
- Do not confuse wrench size with bolt diameter. For a listing of the common wrenches used on various bolt diameters, see **Basic tool requirements**.

**Table a. General bolt tightening torques in Nm
(max. permissible)**

Bolt Class (according to DIN 267)						
Bolt diameter	5.6	5.8	6.8	8.8	10.9	12.9
M5	2.5	3.5	4.5	6	8	10
M6	4.5	6	7.5	10	14	17
M8	11	15	18	24	34	40
M10	23	30	36	47	66	79
M12	39	52	62	82	115	140
M14	62	82	98	130	180	220
M16	94	126	150	200	280	340
M18	130	174	210	280	390	470

Gaskets and seals

Gaskets are designed to crush and become thinner as the mating parts are bolted together. Once a gasket has been used, it is no longer capable of making as good a seal as when new, and is much more likely to leak. For this reason, gaskets should not be reused.

Some gaskets and seals are directional. Make sure that these are installed correctly. In places where a shaft must pass through a housing, flexible lip seals are used to keep the lubricating oil or grease from leaking out past the rotating shaft. Seals should never be reused once they have been removed. When removing a seal, be careful not to damage the metal surfaces.

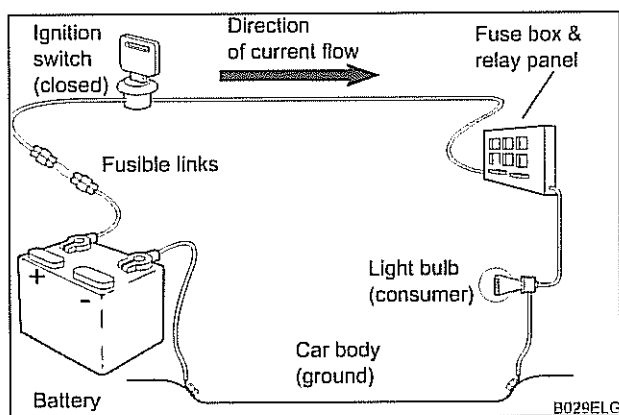
The key to seal installation is to get the seal in straight without damaging it. Use a seal driver that is the same diameter as the seal housing to gently and evenly install into place. If a proper size seal driver is not available, a socket of the right size will do.

Some seals are directional and special installation instructions apply. Make sure a seal is installed with the lip facing the correct way. Note the installation direction of the old seal before removing it.

Electrical testing

Many electrical problems can be understood and solved with only a little fundamental knowledge of how electrical circuits function.

Electrical current only flows in a complete circuit. To operate, every electrical device in the car requires a complete circuit including a voltage source and a path to ground. The positive (+) side of the battery is the original voltage source, and ground is any return path to the negative (-) side of the battery, whether through the wiring harness or the car body. Except for portions of the charging system, all electrical current in the car is direct current (DC) and flows from positive (+) to negative (-).



Switches are used to turn components on or off by completing or interrupting the circuit. A switch is "open" when the circuit is interrupted, and "closed" when the circuit is completed. See **600 Electrical System—General** for electrical troubleshooting.

Wire repairs

Repairs to a wiring harness require special care to make the repair permanent. The wire ends must be clean. If frayed or otherwise damaged, cut off the end and remove enough insulation to complete the repair. If the wire is too short, splice in a new piece of wire of the same size and make two connections.

Use connectors that are designed for the purpose. Crimped on or soldered-on connectors are best. Crimp connectors and special crimping pliers are widely available. If soldering, use needle nose pliers to hold the wire near the solder joint and create a "heat dam". This keeps the heat and the solder from traveling up the wire. Always use a solder made specifically for electrical work (rosin core).

NOTE —

Twisting wires together to make a repair is not recommended. Corrosion and vibration will eventually spoil the connection and may lead to irreparable damage to sensitive electronic components.

Insulate the finished connection. Electronics stores can supply heat-shrinkable insulating tubing that can be placed on to the wire before connecting, slid over the finished joint, and shrunk to a tight fit with a heat gun or hair dryer. The next best alternative is electrical tape. Make sure the wire is clean and free of solder flux or other contamination. Wrap the joint tightly to seal out moisture. See **600 Electrical System—General** for more information.