

Trade of Motor Mechanic

Module 4

Unit 1

BASIC IGNITION SYSTEMS

Produced by

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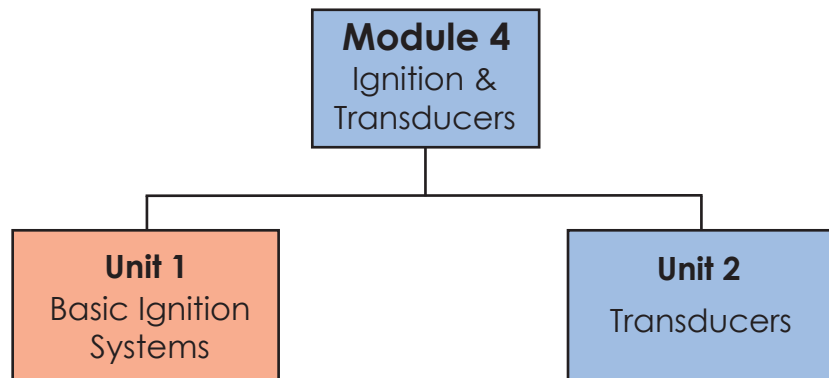
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Introduction

There are 2 Units in this Module. Unit 1 focuses on Basic Ignition Systems and Unit 2 covers Transducers.



Module 4 of this course covers the Ignition and Transducers aspect of automotive technology. This is the first unit in module 4 and introduces the fundamental principles associated with the Basic Ignition System.

The ignition system of an internal-combustion engine is an important part of the overall engine system. It provides for the timely burning of the fuel mixture within the engine. Not all engine types need an ignition system - for example, a diesel engine relies on compression-ignition, that is, the rise in temperature that accompanies the rise in pressure within the cylinder is sufficient to ignite the fuel spontaneously. All conventional petrol engines, by contrast, require an ignition system. These components and the related Health and safety issues are covered in-depth within this unit.

Unit Objective

By the end of this unit each apprentice will be able to:

- Describe the basic function of the ignition system
- Describe the basic operation of a contact breaker switched ignition system
- Describe the basic purpose of ignition timing point setting/advance with regard to engine speed and load.
- Describe the basic purpose of ignition timing point setting/advance with regard to engine speed and load

- State the Health and Safety procedures applicable when working on standard and high energy ignition systems
- Remove a set of High Tension (HT) leads from a training vehicle/unit, measure and compare their electrical resistance to the manufacturer's specification
- Refit the H.T. leads in the correct firing order
- Remove/check the electrode condition of taper-seated and gasket seated spark plugs and refit
- Remove a distributor cap and rotor, check their condition and refit
- Test the electrical resistance of an ignition coil
- Draw a block circuit diagram of a basic electronic ignition system that uses a distributor based signal generator (pick-up)
- Describe the function of the Inductive and Hall type signal generators (pickups) in an electronically controlled ignition system
- Describe the function, basic operating and test principles of the amplifier/switching unit in Inductive and Hall effect electronic ignition systems
- Write a basic illustrated report on the ignition system structure of a training vehicle/unit, its main components type, (i.e. inductive or Hall Effect) their location and basic electrical circuit
- Remove a 'distributor type' pick-up unit, examine the connecting wiring/wiring connections for continuity and electrical resistance, the distributor spindle and drive gear for wear and refit
- State the NCT/DoT VTM requirements for engine idle speed and exhaust system performance
- Test the engine idle speed and exhaust system performance for compliance with NCT/DoT VTM requirements

1.0 Health and Safety Procedures

Key Learning Points

- Danger of electric shock(s) when working on standard or high energy electronic ignition systems, damage to electrical circuitry of heart pacemakers

1.1 Health and Safety Procedures

Although most people think that automotive electrical and electronic systems are low voltage and therefore comparatively safe to work on, that is very far from the reality of the situation.

Modern vehicle high tension systems have very high voltage that can kill. Anyone with a heart pacemaker can also be susceptible to interference from this high voltage which could result in irregular heartbeat and possible coronary arrest as a result of shock from automotive ignition sources.

Misuse of test equipment can cause flashover and damage to the electronic components that can be very expensive to repair. So always follow the correct procedures as outlined in the workshop manual when working on a vehicles electrical and electronics systems.

There is a danger of damaging electronic components with static electricity therefore care has to be taken when handling such items.

Always refer to manufactures recommended procedures when working on ignition systems.

When disconnecting a battery always disconnect the negative terminal first.

When re-attaching a battery always attach the negative terminal last.

Do not wear jewellery that may cause a short circuit with an electrical connection.

Distributors can get quite hot in operation. Make sure you test the temperature of the distributor before you handle it.

Always wear protective clothing and the appropriate safety equipment.

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.

Important Points to Note

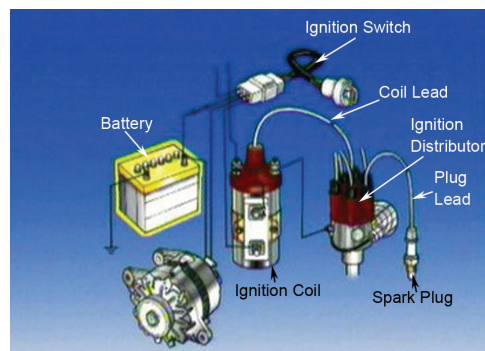
Even though most vehicle electrical systems are described as being 12 volt, they operate at between 13.8 to 14.2 volts. The voltage handled by an ignition system that uses contact breaker points carries between 12,000 - 25,000 volts in the secondary circuit of the system. Therefore care must be taken when the ignition system is activated. They can be fatal especially dangerous around heart pacemakers etc.

2.0 Basic Function of the Spark Ignition System

Key Learning Points

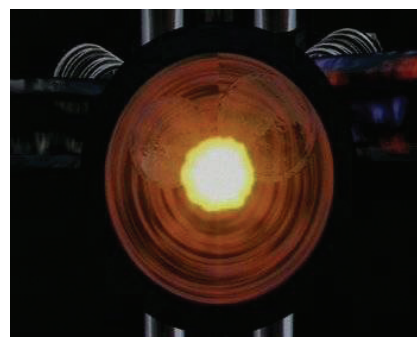
- Function of the ignition system in initiating mixture combustion

2.1 Basic Ignition System



The ignition system of an internal-combustion engine is an important part of the overall engine system. It provides for the timely burning of the fuel mixture within the engine. Not all engine types need an ignition system - for example, a diesel engine relies on compression-ignition, that is, the rise in temperature that accompanies the rise in pressure within the cylinder is sufficient to ignite the fuel spontaneously. All conventional petrol engines, by contrast, require an ignition system. The ignition system is usually switched on/off through a lock switch, operated with a key.

2.2 Ignition Principles



The ignition system provides a spark between the spark plug electrodes. The spark must occur at precisely the right time in the engine cycle and it must have sufficient energy to bridge the gap and ignite the air-fuel mixture under all operating conditions.

The energy required can be obtained from the vehicle's electrical system, but the nominal battery voltage of 12 volts must be increased or "stepped up" to provide a firing voltage of many thousands of volts, typically 18000 volts. This high firing voltage causes the spark gap to become electrically conductive, enabling an ignition spark to occur.

It must have sufficient heat energy to ignite the mixture so that it can continue to burn by itself. Exactly how much energy is required varies according to the condition of the mixture and the pressure in the cylinder at the end of the compression stroke.

With an engine at normal operating temperature and under a light load, a mixture with a ratio close to the ideal ratio of 14.7: 1 ignites readily. However, suddenly depressing the accelerator to increase speed or to maintain speed when hill-climbing, causes cylinder pressures to rise. This increases the firing voltage needed.

The ignition system is designed to have reserve energy available in excess of its normal requirements so that it is able to produce ignition, even when conditions are unfavourable.

Most light vehicle ignition systems are of the inductive type: they use an induction coil with primary and secondary windings to "step-up" the nominal 12 volts at the battery to the required firing voltage.

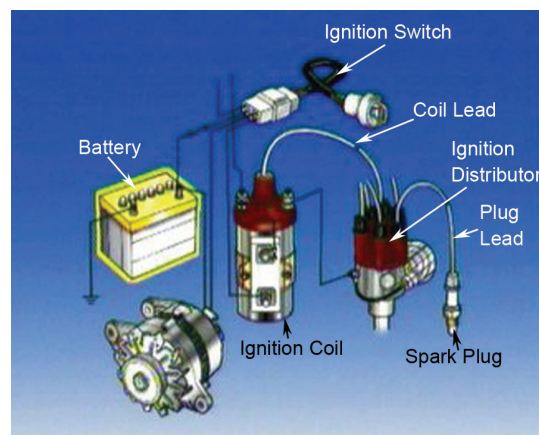
The automotive ignition system is divided into two electrical circuits -- the primary and secondary circuits. The primary circuit has low voltage. This circuit operates only on battery voltage and is controlled by the breaker points and the ignition switch. The secondary circuit has high voltage it consists of the secondary windings in the coil, the high tension lead between the distributor and the coil (commonly called the coil wire) on external coil distributors, the distributor cap, the distributor rotor, the spark plug leads and the spark plugs.

3.0 Operation of a Contact Breaker Ignition System

Key Learning Points

- Standard, contact breaker switched ignition system, mechanical switching of primary circuit, limitations of use, service requirements etc.
- Principles of electro-magnetic induction, self and mutual induction, turns ratio of a transformer

3.1 Mechanical Ignition



Most four-stroke engines have used a mechanical ignition system. Here, the power source is a lead-acid battery, kept charged by the car's electrical system, which generates electricity using an alternator. The engine operates contact breaker points, which interrupt the current flow to an induction coil (known as the ignition coil) - a type of autotransformer. The steps up the voltage, which is fed via a rotating switch called a distributor to the spark plugs. There are also advantages to this arrangement. For example, the position of the contact breaker points relative to the engine angle can be changed a small amount dynamically, allowing the ignition timing to be automatically advanced with increasing revolutions per minute (RPM), giving better efficiency. This system was used almost universally until the late 1970s, when electronic ignition systems started to appear. (We will cover this system later).

A basic ignition system consists of:

- battery
- low-tension cables
- ignition coil
- distributor,
- coil high-tension cable
- spark plug cables
- spark plugs

The ignition system provides high-intensity sparks at the spark plugs, to ignite the fuel charges in the combustion chambers. The sparks must be supplied at the right time and they must have sufficient energy, over a range of conditions, to ignite the charges. The energy comes from the battery and alternator and the voltage is increased by the ignition coil. The system has two circuits. The primary or low-tension circuit initiates the spark.

The secondary or high-tension circuit produces the high voltage and distributes it to the spark plugs.

There are three general types of ignition systems:

- *Breaker ignition* uses contact breaker points in a distributor to initiate the spark.
- *Electronic ignition* doesn't need contact points. When a signal is received, triggering occurs through transistors in an ignition module.
- *Direct ignition* has no distributor and uses coils to supply high-voltage direct to the spark plugs.

3.2 The Battery

The battery provides a source of energy to supply current to the ignition primary circuit for initial starting purposes. It forms part of the ignition primary circuit and acts in conjunction with the alternator to supply current to the ignition system throughout engine operation.



3.3 Ignition Coil

The ignition coil is a step-up transformer, which raises the nominal battery voltage of 12 volts up to the many thousands of volts necessary to provide a spark across the spark plug electrodes. A standard ignition coil has a rod-shaped laminated iron core, which is located centrally by an insulator at its base.



The secondary winding with 15,000 to 30,000 turns of very thin enamelled copper wire is wound around the core and is insulated from the core by layers of treated insulated paper. The primary winding, with a few hundred turns of much heavier copper wire, is wound on the outside of the secondary.

A shield of soft iron surrounds the outer windings and the complete assembly is inserted into a one-piece steel or aluminium container. The container is then filled with special transformer oil, which provides good electrical insulation and also permits rapid heat dissipation.

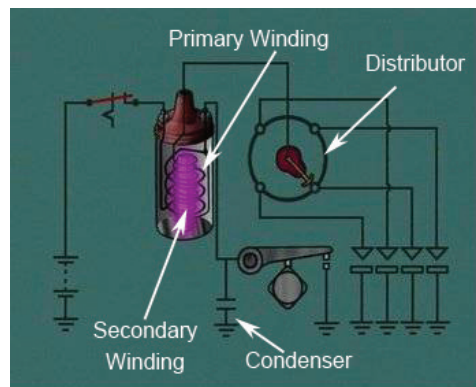
The cap has two terminals, positive and negative, for external connection to the primary circuit. The ends of the primary winding are connected internally to each. Provision is also made externally for a heavy insulated centre terminal to connect the high tension coil lead to the distributor cap.

One end of the secondary winding is connected to this centre terminal and the other end is connected to one end of the primary winding. A rubber seal and a moulded insulated cap seal the assembly in the container and the container edges are swaged over to bind the coil into a compact vibration free unit.

Primary & Secondary Windings

The two main sections of an ignition system coil are:

Primary Windings and *Secondary Windings*



On a breaker contact points system:

The *primary circuit is the low voltage side*. It includes:

- Power source from the battery
- In some instances, ballast resistor
- Primary windings connecting to:
 - Contact breaker points
 - Condenser
 - To earth thus completing an electrical circuit.

The *secondary circuit is the high voltage side*. It includes:

- Secondary windings connected to coil tower output terminal
- High tension lead to centre terminal of the distributor cap
- Makes an electrical circuit to the rotor
- Aligns with each terminal output post
- High tension leads connecting to the spark plug(s).

Operation

With the ignition switched on and the contact breaker closed, current flows from the positive battery terminal, through the ignition switch, the primary winding and the contact breaker to ground, then back to the negative battery terminal.

The current flow establishes a magnetic field around the windings. The field is intensified by the rod-shaped laminated iron core.

With engine rotation, the lobe on the distributor cam acts on the heel of the moving contact point at the instant ignition is required. This opens the contacts and stops current flow through the primary circuit. This sudden interruption of current flow collapses the magnetic field and it returns its stored energy to the coil terminals by cutting across the coil windings. This induces a voltage in the primary and secondary winding.

Since the secondary winding has about 100 times as many turns as the primary winding, the secondary voltage can also be about 100 times greater than the induced primary voltage.

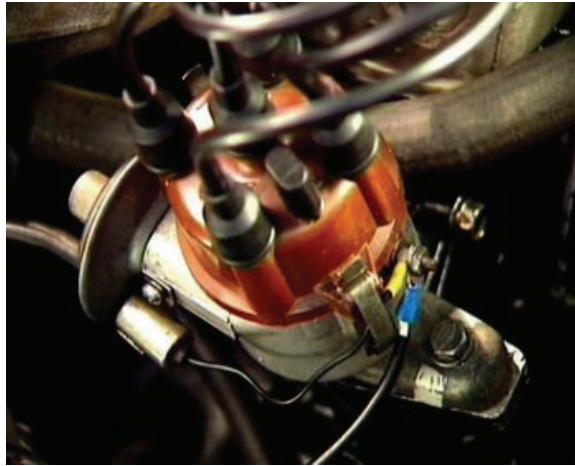
As the high tension voltage builds up across the ends of the secondary winding, a voltage level is reached where the spark plug gap suddenly becomes conductive. A spark then bridges the gap between the rotor and the distributor cap segment and also the gap between the spark plug electrodes.

The secondary circuit is from its connecting point at the primary winding, to the spark plug and across its electrodes to ground. From there it is completed through the battery and primary circuit, back to its connecting point.

Opening and closing the contact breaker switches the primary current off and on.

3.4 Distributors

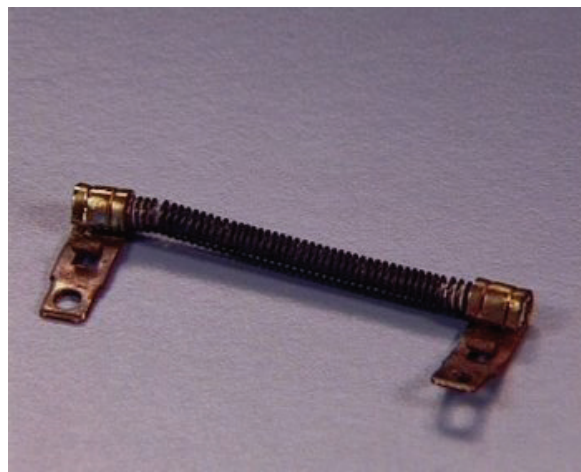
The distributor in the ignition system of an internal combustion engine is a device which routes the high voltage in the correct firing order to the spark plugs. It consists of a rotating arm or rotor inside the distributor cap, on top of the distributor shaft. The rotor contacts the central high voltage cable from the coil via a spring loaded carbon brush. The rotor arm passes close to (but does not touch) the output contacts which connect via high tension cables to the spark plug of each cylinder. Within the distributor, the high voltage energy is able to jump the small gap from the rotor arm to the contact. The distributor shaft has a cam that operates the contact breaker. Opening the points causes a high induction voltage in the ignition system's coil.



The distributor also houses the centrifugal advance unit: a set of hinged weights attached to the distributor shaft, that cause the breaker points mounting plate to slightly rotate and advance the spark timing with higher engine rpm. In addition, the distributor has a vacuum advance unit that advances the timing even further as a function of the vacuum in the inlet manifold. Usually there is also a capacitor attached to the distributor. The capacitor is connected parallel to the breaker points, to suppress sparking and prevent wear of the points.

3.5 Ballast Resistor

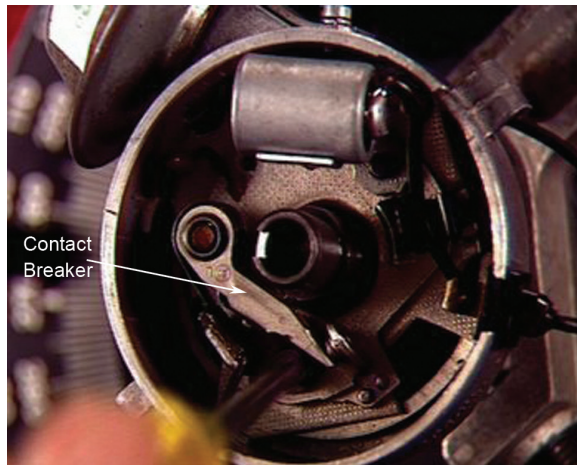
A ballast resistor is an electrical resistor that is diverted into and out of the supply voltage to the ignition coil system. This ballast resistor actually lowers voltage after the engine is started to reduce or minimize wear on ignition components. It also helps the engine to fire much easier by effectively doubling the voltage provided to the ignition coil when the engine is being cranked. Not all car manufacturers used a ballast resistor in their ignition systems. The ballast resistor is a resistance wire which is inserted in series in the primary circuit between the ignition switch and the positive terminal of the ignition coil.



The heat sensitive type is wound onto a heat resistant former and placed in an open ceramic holder with connecting terminals at each end. It is normally located close to the ignition coil in an exposed position, so that it can transfer its heat easily to the air. The purpose of the ballast resistor is to drop the nominal battery voltage down to approximately half its value for ignition coil operation.

3.6 Contact Breaker

The contact breaker is a mechanically operated electrical switch which is fixed to the distributor base plate and opened and closed by the distributor cam with the rotation of the engine. The contacts normally form a self-contained unit, fixed to the base plate by a retaining screw engaged in a slot in the fixed contact. The slot allows for adjustment of the contact breaker gap and the setting of the dwell angle when fitting or servicing.



Function

In standard ignition, the contact set is attached to the movable breaker plate. A vacuum advance unit attached to the distributor housing is mounted under the breaker plate. The rotor covers the centrifugal advance mechanism, which consists of a cam actuated by two centrifugal weights. As the breaker cam rotates, each lobe passes under the rubbing block, causing the breaker points to open. Since the points are in series with the primary winding of the ignition coil, current will pass through that circuit when the points close. When the points open, the magnetic field in the coil collapses and a high tension voltage is induced in the secondary windings of the coil by the movement of the magnetic field through the secondary windings.

Limitations

Contact breaker points suffer from wear - both mechanical (due to the fact that they open and close several times every turn of the engine) and caused by arcing across the contacts.

The main problem lies in the fact that the contact breaker points gradually burn and become pitted. This is normal wear and tear for this system. The problem arises with the metal from one point being transferred to the other. Under normal maintenance procedures, if this built-up metal cannot be removed with a points file, the contact breaker points should be replaced with a new set as recommended by the vehicle manufacturer or component manufacturer.

3.7 Dwell Angle

The dwell angle is the number of degrees of rotation of the cam/distributor during which the points are closed. During each rotation of the cam/distributor, the points must open and close once for each cylinder. The points must stay closed long enough to allow the coil primary current to reach an acceptable value, then open long enough to discharge and produce a spark.



The engine makes two complete revolutions 720 degrees in the same time that the distributor makes one 360 degree revolution.

Functionality

With the primary circuit being switched on and off repeatedly each coil has to be designed for a particular application so that it operates efficiently.

For a four stroke 4 cylinder engine running at 2000 RPM, 4000 sparks must be supplied every minute. The time available to make and break the primary circuit each time is very short. As engine speed rises, the time available is even shorter. It is very important then to ensure that the length of time current flows through the primary winding is sufficient to create the necessary magnetic field.

In contact breaker systems this brief period of time is the period during which the contacts are closed. This is referred to as the “dwell angle”. It is usually specified in degrees of distributor rotation.

This closed period is influenced by the setting of the contact breaker gap. Once this has been set, the angle remains fixed regardless of engine speed.

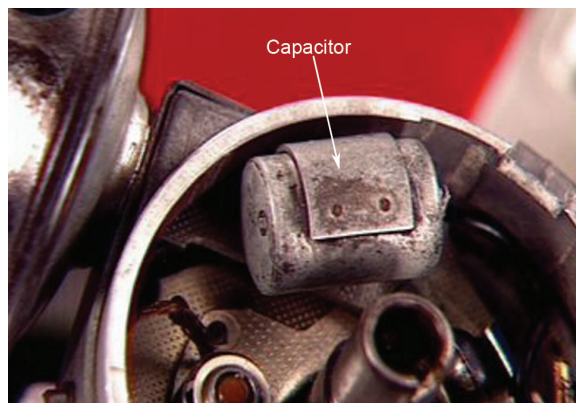
A large gap gives a small dwell angle. A small gap gives a large dwell angle.

The manufacturer’s recommended gap provides the specified dwell angle for each application and those recommendations should be followed.

3.8 Capacitor/Condenser

The capacitor (also called a condenser), is a self contained unit which is connected electrically in parallel with the contact breaker. The capacitor is connected parallel to the breaker points, to suppress sparking and prevent wear of the points.

It is made up of two “plates” constructed from narrow strips of aluminium foil which are insulated from each other by a special waxed paper, called a “di-electric.” The plates and insulating paper are rolled up tightly together and sealed in a metal can by crimping the end over onto a gasket.



A spring in the base forces the plates and insulation against the gasket to keep out moisture. One plate is connected to the capacitor case and, through its retaining screw, to ground. The other plate is connected to the external connecting lead.

One of the drawbacks of the process is the interruption of current in the primary coil generates an inductive back-voltage, called “Back EMF”, in the coil which tended to cause sparking across the points. This process is corrected by fitting a capacitor across the contacts so that the voltage surge will charge the capacitor rather than cause destructive sparking across the contacts.

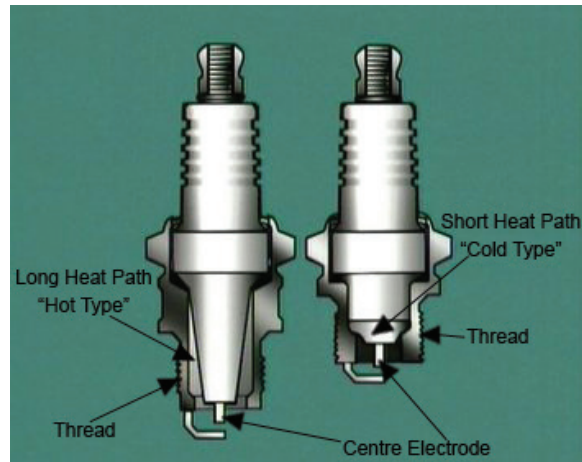
3.9 High-Tension Leads

The high tension cables conduct the high output voltage generated in the secondary ignition circuit when each ignition pulse occurs. They link the high tension terminal of the ignition coil, the distributor cap and spark plugs.



Because of the high voltage, the cables are large in diameter and are made from thick-walled insulating material around a central conducting core. The heavy insulation prevents leakage occurring and also withstands the effects of high temperature, oil and moisture. The core of the cable is made of carbon-impregnated linen or fibreglass. It has a specific ohms resistance value. A crimped terminal at each end provides for connection of the components. When removing or fitting these leads handle them with care as they can be damaged easily.

3.10 Spark Plugs



A spark plug is an electrical device that fits into the cylinder head of some internal combustion engines and ignites compressed air and petrol by means of an electric spark.

Spark Plug Construction

A spark plug is composed of a shell, insulator and the conductor. It pierces the wall of the combustion chamber and therefore must also seal the combustion chamber against high pressures and temperatures, without deteriorating over long periods of time and extended use. The spark plug consists of a plated metal shell with a ceramic insulator and an electrode extending through the centre of the insulator. Threads on the metal shell allow it to be screwed into the cylinder head and a short earth electrode attached to one side is bent in towards the centre electrode. The electrodes are of special alloy wire with a set recommended gap between them. The spark bridges this gap to ignite the air-fuel mixture in the combustion chamber. Spark plugs are identified by three different features.

These are:

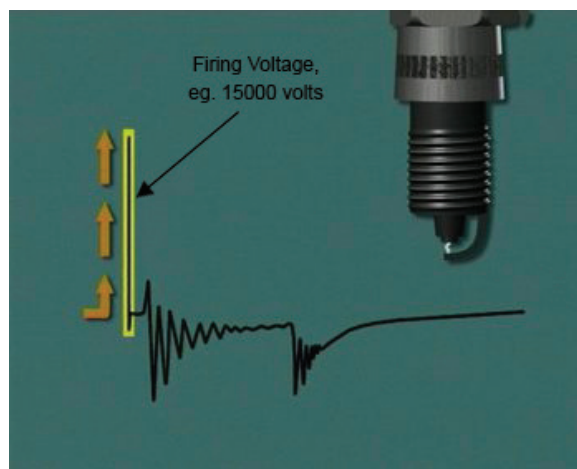
- Thread size or diameter.
- Reach or length of the thread.
- Heat range or operating temperature.
- Plug firing voltage

Plug Firing Voltages

While the perception that the spark plugs fire instantaneous, this is not technically correct it can take milliseconds to fire which can be measured using an oscilloscope.

The coil operates according to Faraday's Law of electro-magnetic induction.

As the high tension voltage in the secondary winding builds up, a particular voltage level is reached when the spark plug gap suddenly becomes conductive, allowing the spark to occur. This is known as the "plug firing voltage".



The firing voltage is Approximately 15,000 volts; the level of plug firing voltage depends on many factors, such as:

- The mixture density.
- Turbulence.
- The pressure in the cylinder.
- The spark plug gap.
- The condition of the spark plug electrodes.
- The resistance of the secondary circuit.

3.11 Engine Firing Order

The *firing order* is the sequence of sparking of the spark plugs in a reciprocating engine, or the sequence of fuel injection in each cylinder in a Diesel engine. Choosing an appropriate firing order is critical to minimizing vibration and achieving smooth running, for long engine fatigue life and user comfort.

In a straight engine the spark plugs (and cylinders) are numbered, starting with number 1, from the front of the engine to the rear. In most cars the front of the engine also points to the front of the car, but some manufacturers in some models place the engine 'backwards', with number 1 towards the firewall.

These are some common firing orders:

<i>Number of cylinders</i>	<i>Firing order</i>	<i>Example</i>
3	1-2-3	Daihatsu charade (03-)
4	1-3-4-2	Toyota Yaris 1lt (99-06)
5	1-2-4-5-3	Volvo C70 (97-98) 2.5
6	1-5-3-6-2-4	Bmw Z4 (E85) 3.0

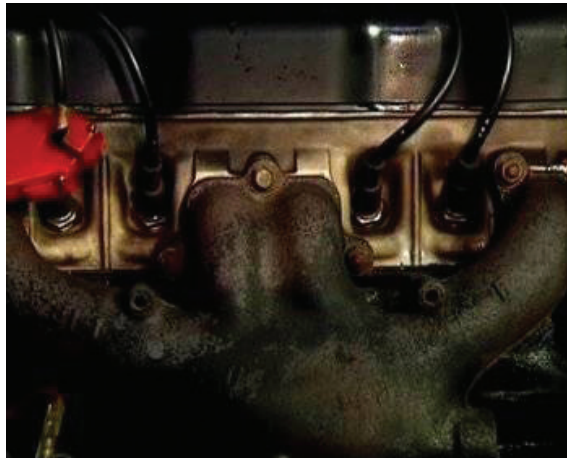
4.0 The Basic Purpose of Ignition Timing

Key Learning Points

- Relationship between ignition timing and internal combustion chamber pressure, max pressure 13° A.T.D.C., effects of variable engine speed and load

4.1 Spark Timing Contact Breaker Ignition

Timing of the spark is normally set at idle speeds by positioning the distributor body in relation to its rotating cam. The timing is set on Number One cylinder and the contacts are operated in turn by each cam lobe to provide the same timing point for succeeding cylinders in the firing order. This initial setting before T.D.C. allows time for maximum pressure in the cylinder to be developed just as the piston is descending on the power stroke, approximately 13° A.T.D.C.



However, as engine speed increases there is less and less time for the mixture to be ignited and for this maximum pressure to be developed. So the ignition point has to be advanced this must occur automatically in relation to engine speed and engine load.

The speed sensitive mechanism is a centrifugal type which is located beneath the distributor base plate and rotates with the distributor cam. As engine speed rises, the flyweights on the advance mechanism are thrown outward by centrifugal force. Since the cam is able to pivot on the distributor shaft, the weights act against their springs and move the cam forward.

Under these conditions, the quantity of mixture entering the cylinder is reduced and the air-fuel ratio is set for maximum economy, on a lean setting. This type of mixture burns more slowly and therefore must be ignited earlier in the cycle to derive maximum benefit from the fuel.

The load sensitive mechanism is a vacuum advance unit which is operated by intake manifold vacuum via a port on the carburettor or the fuel injection throttle body. The port is connected by a vacuum line to a sealed chamber on one side of a spring loaded diaphragm. A mechanical link on the other side connects the diaphragm to the distributor base plate. The base plate is moveable and can be rotated, in relation to the distributor body, in the opposite direction to the distributor cam rotation.

The port in the throttle body is above the throttle plate when the engine is idling and no vacuum can reach the advance unit. However at light throttle openings, the vacuum port is exposed and manifold vacuum is transmitted to the sealed chamber. The diaphragm moves against the spring to rotate the base plate and since the base plate carries the contact breaker, the contacts meet the distributor cam earlier in rotation, advancing the spark.

As the throttle is opened wider, there is less vacuum effect in the manifold and consequently less vacuum advance. At wide open throttle openings, there will be no vacuum advance at all and ignition advance will be determined solely by the speed sensitive mechanism.

4.2 Advance & Retard Mechanisms

Advance and retard mechanisms are used to vary the ignition timing to suit different engine operating conditions.



The centrifugal advance mechanism rotates with the distributor shaft inside the distributor housing and advances ignition timing as the engine speed increases.

Ignition advance in relation to engine load is catered for by a vacuum advance unit which has a vacuum line connection to a port on the intake throttle body.

If the engine ignition timing has been retarded too far then the engine will tend to knock or ping.

4.3 Ignition Timing and Knocking

Knocking (also called pinking) in internal combustion engines occurs when fuel in the cylinder is ignited by the firing of the spark plug and smooth burning proceeds but some of the unburned mixture in the combustion chamber explodes before the flame front can reach it, combusting suddenly before the optimum moment of the four-stroke cycle. The resulting shockwave reverberates in the combustion chamber creating a characteristic metallic “pinging” sound.

Detonation

The fuel/air mixture is normally ignited slightly before the point of maximum compression to allow a small time for the flame-front of the burning fuel to expand throughout the mixture, so that maximum pressure occurs at the optimum point (approximately max pressure 13° A.T.D.C). The flame-front moves at roughly 34 metres/second during normal combustion. It is only when the remaining unburned mixture is heated and pressurized by the advancing flame front for a certain length of time that the knocking effect occurs. It is caused by an instantaneous ignition of the remaining fuel/air mixture in the form of an explosion. The cylinder pressure rises dramatically beyond design limits. If allowed to persist detonation will cause vibration and damage to engine parts.

Detonation can typically be prevented by:

- The use of a fuel with higher octane rating.
- The addition of octane-increasing "lead", isooctane or other fuel additives.
- Reduction of cylinder pressure by increasing the engine revolutions or reducing the load on the engine, or both.

- Reduction of in-cylinder temperatures (such as through cooling or compression ratio reduction).
- Retardation of spark plug ignition.
- Adding water in the form of vapour in the air intake.
- Proper combustion chamber design which concentrates mixture near the spark plug and generates high turbulence to promote fast even burning.
- Use of a spark plug of colder heat range in cases where the spark plug insulator has become a source of pre-ignition leading to detonation.

Correct ignition timing is essential for optimum engine performance and fuel efficiency. Modern automotive engines have sensors that can detect knock and delay the spark plug firing to prevent it, allowing engines to safely use petrol of lower octane ratings, with the consequence of reduced power and efficiency.

A knock sensor consists of a small piezoelectric microphone on the engine block, connected to the engine's electronic control unit.

Pre-Ignition

Detonation, as previously explained, is a different phenomenon from pre-ignition, which occurs when the air/fuel mixture in the cylinder (or even just entering the cylinder) ignites before the spark plug fires. Pre-ignition is accompanied by a loud hacking noise and caused by an ignition source other than the spark. Heat can build-up in the engine intake or cylinder components due to improper design e.g. spark plugs with too low a heat rating, carbon deposits in the combustion chamber, or also due to overheating of the air/fuel mixture during compression. This heat build-up can only be prevented by eliminating the overheating (through redesign or cleaning) or the compression effects (by reducing the load on the engine or temperature of intake air). As such, if pre-ignition is allowed to continue for any length of time, power output reduces drastically and engine damage can result.

5.0 High Tension (HT) Leads Removal and Testing

Key Learning Points

- The need for extreme care to avoid electrical insulation damage to H.T. leads/shrouds when working on high energy ignition systems
- Use of manufacturers recommended procedures for maintenance of the ignition system e.g. spark plug and H.T. lead removal and refitting procedures
- Engine not run with H.T. leads on open circuit, i.e. possible electrical arcing damage to the coil and un-burnt fuel to catalytic converter

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

6.0 H.T. Leads-Refitting

Key Learning Points

- Firing orders of various engine configurations

See section 3.11 for a diagram of firing order.

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

7.0 Checking Spark Plug Condition

Key Learning Points

- Spark plug, basic construction and design features, removal/refitting/tightening/torquing procedures (flat seat; +90°, conical seat; +150°)

7.1 Spark Plugs

Covered in Section 3.10

7.2 Checking & Changing a Spark Plug

Objective

Check and change a spark plug.

Safety Check

- Never try to check or change a spark plug while the engine is running.
- Make sure the bonnet stay 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

The leads which come from the distributor (or from the high tension coils in the case of a “wasted spark” type system) must be removed from the spark plug in such a way that you can identify which cylinder they belong to. If the leads are replaced on the wrong spark plug, the engine may misfire or not run at all. Some mechanics make a habit of only removing one spark plug at a time, cleaning or repairing it and then replacing the plug and reconnecting the lead before servicing the next plug.

Disconnect the high-tension lead by pulling on the boot where it connects to the plug; if you pull on the wire itself, you can easily damage the wiring. *Always refer to manufacturers instructions.*

Spark plug bodies are made of a ceramic material that is brittle and fragile. Always use a proper spark plug socket to remove them. This will reduce the risk of damaging the plug.

What to Look for When Changing Spark Plugs

- Light brown or grey deposits: Clean, adjust and *refit old plug*.
- Severely worn electrodes: *fit new plug*.
- Burnt material, melted electrodes, blistering: *fit new plug*.
- Carbon-fouled plug, sooty black deposits: *report* for diagnosis of other engine problem or for a possible *change* to alternate plug type.
- Oily deposits: *report* for diagnosis of cause of oil leak.

Step by Step Instruction

1. *Remove the spark plug lead/coil assembly:* Before removing the spark plug, disconnect the spark plug high tension lead by grasping the boot where it connects to the plug, twist it and pull it firmly straight out
2. *Clean loose dirt away:* If possible, use a small paint brush to clean away any loose dirt or dust gathered round the base of the plug, which may fall into the cylinder when the plug has been removed.
3. *Select correct spark plug tool:* The correct tool to use is a spark plug socket. This usually has a rubber insert to protect the plug while it is being removed.

4. *Remove the spark plug:* Spark plugs can sometimes be difficult to remove, so you may need to extend the wrench handle for additional leverage. Turn the plug counter-clockwise to loosen it and then turn the socket by hand until you can remove it.
5. *Clean the plug and check condition:* Remove the spark plug from the socket and clean it, brushing away any light deposits with a wire brush.
6. *Check the condition of the plug.:* If the insulator is cracked, or the electrodes are burned or heavily corroded, or the thread is stripped, then the plug will need to be replaced. If the plug is dirty or oily, this may indicate a problem elsewhere and you should report this to your instructor.
7. *Check and adjust the gap:* Check the plug specifications for the correct gap and measure this with a wire gauge of the correct diameter. If the gap between the electrodes is too wide or too narrow, adjust it by bending the ground electrode with a gap-adjusting tool.
8. *Obtain replacement plug:* There are hundreds of different spark plugs, so make sure that any replacement you install has the correct code number for the type of vehicle you are servicing.
9. *Refit the spark plug & torque to spec.:* Replace the spark plug in its seat, carefully screwing it in by hand to avoid stripping the thread. Use a torque wrench to tighten the plug to the correct specification. Do not over tighten as this can damage the plug. Refer to manufacturer's specification at all times.
10. *Refit the spark plug lead/coil assembly.:* Apply special lubricant to the inside of the boot at the end of the coil lead and push it firmly into place over the exposed spark plug terminal.
11. *Start the engine.:* To confirm that the plugs and leads are working correctly and that the engine is not misfiring.

8.0 Servicing Distributor Cap/Rotor

Key Learning Points

- Fitting the distributor correctly

Practical Task *Please refer to your instructor for additional information.*

9.0 The Electrical Resistance of an Ignition Coil

Key Learning Points

- Electrical resistance of the coil primary and secondary windings measured and compared to manufacturer's specifications

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

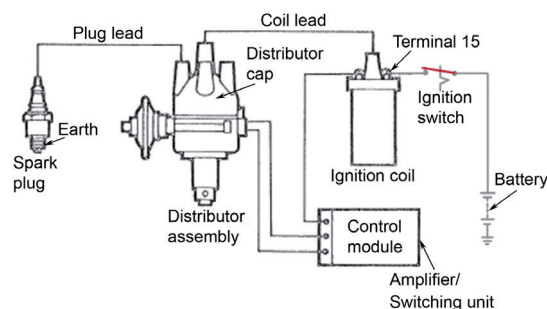
10.0 Diagram of a Basic Electronic Ignition System

Key Learning Points

- 'Block' type ignition system circuit diagram showing distributor type pick up, amplifier/switching unit, coil, plugs and connectors

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

10.1 Sample Diagram



Inductive Type Pulse Generator

11.0 Inductive and Hall Type Signal Generators in Ignition Systems

Key Learning Points

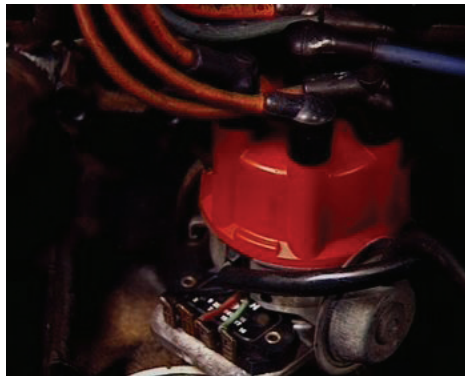
- Basic operation and test procedures of the operation of Inductive and Hall effect electronic ignition systems e.g. test lamp across the coil during engine cranking (Unit 2; Transducers)

Practical Task *Please refer to your instructor for additional information.*

11.1 Electronic Ignition; Induction

Background

The disadvantage of the mechanical system is that it requires regular adjustment to compensate for wear and the opening of the contact breakers, which is responsible for spark timing, is subject to mechanical variations. In addition, the spark voltage is also dependent on contact effectiveness and poor sparking can lead to lower engine efficiency. Electronic ignition (EI) solves these problems.



In an EI system, the contact breaker points are replaced by an angular sensor of some kind – either optical, where a veined rotor breaks a light beam, or more commonly using a Hall effect sensor, which responds to a rotating magnet mounted on a suitable shaft. The rest of the system (distributor and spark plugs) remains as for the mechanical system. The lack of moving parts compared with the mechanical system leads to greater reliability and longer service intervals. For older cars, it is usually possible to retrofit an EI system in place of the mechanical one.

Operation

In electronic ignition systems the contact breaker is eliminated and the switching or triggering of the primary circuit is carried out electronically. In induction type systems, the pulse generator has a stator mounted on the distributor body and a rotor unit, called a reluctor, attached to the distributor shaft. The stator has a circular permanent magnet with a number of projections or teeth corresponding to the number of engine cylinders and a stationary coil of fine enamelled copper wire wound on a plastic reel and positioned inside the magnet. The reluctor has the same number of teeth as the stator and, as it rotates, these teeth approach and leave the stator teeth, changing the air gap between them. As this occurs, the strength of the magnetic field changes, increasing as the teeth approach, reaching a maximum when they are in alignment and decreasing as they move away.

As the stationary winding is influenced by the magnetic field, then, in accordance with Faraday's Law, a voltage is induced across the ends of the winding, each time the magnetic field changes. And if the winding forms part of a complete circuit, the voltage will cause a current to flow.

As the teeth approach, the strength of the magnetic field is increasing. This induces a voltage and current flow in the winding. The polarity of the voltage is said to be positive as it produces a current flow in a certain direction. When the teeth are in alignment, the magnetic field is at its strongest but; at that point, it is not changing. Voltage and current now fall to zero.

As the teeth move away, the strength of the magnetic field changes again and once again voltage and current flow is induced in the winding. This time, current flow is in the opposite direction and the polarity is now said to be negative. Since polarity changes every time the teeth approach and leave the stator teeth, the voltage produced is an A.C. voltage and current flow is an alternating current.

11.2 Inductive System Operation

In an electronic ignition, a rotating reluctor and magnetic-pickup coil replace the traditional cam, breaker points and condenser in the distributors of cars equipped for electronic ignition. This system reduces the time between tune-ups. The high spots of the reluctor interrupt the magnetic field of the pickup coil and the permanent magnet.



These interruptions, or pulses, are transmitted from the pickup to a nearby electronic control unit. There, the pulses signal a transistor to break the low-voltage sub-circuit and release high voltage from the coil to the spark plugs. After the positive pulse is received, a dwell control section of the control circuit determines when the primary circuit will be switched on and how long current will flow in the primary winding. The dwell period can thus be varied according to engine speed, improving coil efficiency. At low engine speeds, the dwell period is short. As engine speed rises the dwell period increases. Ignition coils employed with electronic systems are referred to as low inductance coils, because their primary winding resistance and number of turns is low. Current flow is much higher than with contact breaker systems and reaches its optimum level sooner.

A current limiting device within the control circuit limits maximum current flow to a safe value. Ignition advance according to engine speed and load is provided by centrifugal and vacuum advance mechanisms.

11.3 Electronic Ignition System Components

The components of a basic electronic ignition system all perform the same functions. Manufacturer has their own preferred terminology and location of the components.

The basic components of an electronic ignition system are as follows:

Trigger Wheel: The trigger wheel, also known as a reluctor, pole piece, or armature, is connected to the upper end of the distributor shaft. The trigger wheel replaces the distributor cam. Like the distributor cam lobes, the teeth on the trigger wheel equal the number of engine cylinders.

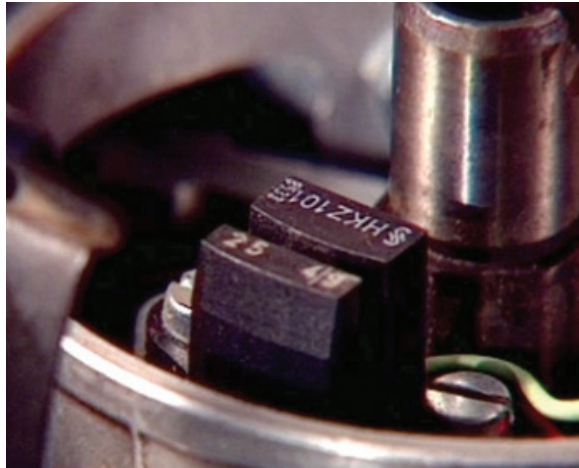
Pickup Coil: The pickup coil, also known as a sensor assembly, sensor coil, or magnetic pickup assembly, produces tiny voltage surges for the ignition systems electronic control unit. The pickup coil is a small set of windings forming a coil.

Electronic Control Unit Amplifier: The ignition system electronic control unit amplifier or control module is an “electronic switch” that turns the ignition coil primary current ON and OFF. The ECU performs the same function as the contact points. The ignition ECU is a network of transistors, capacitors, resistors and other electronic components sealed in a metal or plastic housing. The ECU can be located in the engine compartment, or on the side of the distributor, or inside the distributor, or under the vehicle dashboard.

ECU dwell time (number of degrees the circuit conducts current to the ignition coil) is designed into the electronic circuit of the ECU and is NOT adjustable. When the distributor shaft rotates, a fluctuating magnetic field is generated due to changes in the air gap between the crank angle sensor and the distributor shaft reluctor.

11.4 Hall Effect Sensors

In electronic ignition systems, the contact breaker is eliminated and switching and triggering of the primary circuit is carried out electronically. In Hall Effect systems, a Hall Effect generator can be located inside the distributor to signal an electronic control unit to turn the primary circuit “on” and “off”. Hall Effect generators operate by using a potential difference or voltage created when a current carrying conductor is exposed to a magnetic field.



If a magnetic field is applied at right angles to the direction of current flow in a conductor, the lines of magnetic force permeate the conductor and the electrons flowing in the conductor are deflected to one side. This deflection creates a potential difference across the conductor.

The stronger the magnetic field, the higher the voltage. This is called the Hall Effect voltage and if the magnetic field is alternately shielded and exposed, it can be used as a switching device. Hall devices are made of semi-conductor material because it produces a better effect.

In a distributor, the Hall Effect generator and its integrated circuit or IC, are located on one leg of a “U” shaped assembly, mounted on the distributor base plate. A permanent magnet is located on the other leg and an air gap is formed between them. An interrupter ring, which has the same number of blades and windows as engine cylinders, is rotated by the distributor shaft, moving the blades through the air gap.

When a window is aligned with the assembly, the magnetic field is at its strongest and its lines of magnetic force permeate the Hall generator and its integrated circuit. This allows the generator to switch to ground the low current signal voltage applied to it. When the interrupter ring rotates so that the blade aligns with the assembly, the magnetic field is shielded from the generator and the signal voltage is not switched to ground.

With continuous rotation, the blades repeatedly move in and out of the air gap and the signal voltage will appear to turn on and off repeatedly. This can be used to control the operation of the ignition coil primary circuit.

12.0 Servicing the Electronic Ignition System Amplifier

Key Learning Points

- Basic operation of the amplifier (transistor as a switch) unit in Inductive and Hall Effect ignition systems, switching voltage signal from pick up unit

Covered in section 11.3

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

13.0 Ignition System Reports

Key Learning Points

- Written report on the ignition system main component type/system, description of individual component location and drawing basic circuit diagrams

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

14.0 Testing a 'Distributor Type' Pick-Up Unit

Key Learning Points

- Distributor examined for mechanical/electrical wear/damage, refitted to manufacturer's recommended ignition timing reference point

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

15.0 Engine Idle Speed and Exhaust Performance

Key Learning Points

- NCT/DoT VTM requirements on engine idle speed and Exhaust System/Noise performance

15.1 NCT Requirements

Please refer to item 2, 3 and 54 of the current NCT manual.

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

16.0 Testing Engine Idle Speed and Exhaust System Performance

Key Learning Points

- Idle speed measured using tachometer and Exhaust System/Noise tested for compliance with NCT/DoT VTM requirements

16.1 NCT Requirements

Please refer to item 2, 3 and 54 of the current NCT manual.

Practical Task

Please refer to your instructor for additional information, which is available from the automotive technical manuals.

Self Assessment

Q1: One purpose of the capacitor in a contact breaker coil ignition system is to: (Tick one box only)

- 1. Assist in the rapid collapse of the magnetic field
- 2. Hold a charge until the spark is required
- 3. Break the primary circuit at the correct time
- 4. Prevent arcing at the rotor arm tip

Q2: A spark occurs at the spark plug when the contact points: (Tick one box only)

- 1. Close
- 2. Ignition switch is turned on
- 3. Open
- 4. Ignition switch is turned off

Q3: The voltage output of the secondary windings compared to the primary winding is approximately: (Tick one box only)

- 1. 1,000 times more
- 2. 100 times more
- 3. 10 times more
- 4. The same

Q4: A magnetic field surrounds the coil when: (Tick one box only)

- 1. The ignition switch is on and the points are open
- 2. The ignition switch is on and the points are closed

Q5: The dwell angle is the number of degrees of distributor rotation that the: (Tick one box only)

- 1. Breaker points are open
- 2. Rotor turns between sparks
- 3. Engine cranks over before starting
- 4. Breaker points are closed

Q6: In electronic ignition the high tension spark is produce when the reluctor teeth: (Tick one box only)

- 1. Are opposite the stator teeth
- 2. Approach the stator teeth
- 3. Leave the stator teeth
- 4. Ignition switch turns on

Q7 A low inductance coil primary winding has: (Tick one box only)

- 1. Low resistance and higher current draw
- 2. Low resistance and low current draw
- 3. Resistance so low it cannot be measured
- 4. High resistance and high current draw

Q8: In contact breaker ignition systems, an excessive distributor dwell angle can be corrected by: (Tick one box only)

- 1. Decreasing the contact gap
- 2. Advancing the ignition timing
- 3. Increasing the contact
- 4. Retarding the ignition timing

Q9: Technician A says the coil can produce more voltage at high speeds than at low speeds. Technician B says it can produce consistently high voltages across the engine speed range. Who is correct? (Tick one box only)

- 1. Technician A
- 2. Technician B
- 3. Both Technician A and Technician B
- 4. Neither Technician A nor Technician B

Q10: The names of the windings in the ignition coil are the: (Tick one box only)

- 1. Big and small
- 2. Large and small
- 3. Primary and secondary
- 4. High-tension and low-tension

Q11: A ballast resistor fitted to a coil ignition system is by-passed during engine cranking to ensure that: (Tick one box only)

- 1. Ignition timing is advanced to aid starting
- 2. Maximum current is supplied to the starter motor
- 3. Maximum available battery voltage is applied to the coil
- 4. It is not burned out by the high starter current

Q12: In contact breaker ignition systems, timing can be advanced relative to engine speed by a: (Tick one box only)

- 1. Centrifugal advance mechanism
- 2. Scissors type distributor drive gear
- 3. Ballast resistor
- 4. Moveable breaker plate

Q13: A vacuum advance unit advances ignition timing by moving the distributor base plate: (Tick one box only)

- 1. At wide throttle openings only
- 2. Against the direction of distributor shaft rotation
- 3. According to engine speed
- 4. In the direction of distributor shaft rotation

Q14: Technician A says ignition systems equipped with Hall Effect sensors do not require a ballast resistor to regulate primary current. Technician B says these systems do need a ballast resistor or resistance wire. Who is correct? (Tick one box only)

- 1. Technician A
- 2. Technician B
- 3. Both Technician A and Technician B
- 4. Neither Technician A nor Technician B

Suggested Exercises

1. Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
2. Remove, test the electrical resistance and refit in the correct order, H.T. leads
3. From training vehicle/unit, remove, examine for mechanical wear and refit Inductive and Hall Effect distributor units
4. Use a multi-meter to check the pick-up to amplifier/switching unit live and earth and interconnecting wiring for continuity, excessive resistances etc.

Training Resources

- Technical information in book/electronic form on spark ignition system function, basic design, operation and technical involvement, NCT/DoT VTM test manual, basic schematic, ignition system diagrams
- Training units/vehicles for demo/practical exercises on Inductive and Hall Effect 'pickup' distributors
- Multi-meters and manufacturer's data
- H.T. lead removal tool

Task Sheets

Checking Ignition Timing

Preparation and Safety

Objective

Check ignition timing using timing light.



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:

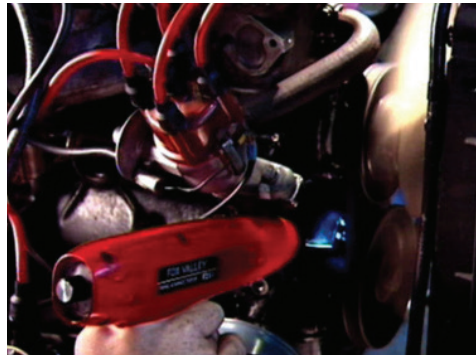
- Work clothing - such as coveralls and steel-capped footwear
- Eye protection - such as safety glasses and face masks
- Ear protection - such as earmuffs and earplugs
- Hand protection – such as rubber gloves and barrier cream
- Respiratory equipment – such as face masks etc.

If you are not certain what are appropriate or required, ask your instructor.

Safety Check

- This method of checking the timing can only be performed with the engine running so the belts and fans are moving. As you point the timing light onto the engine timing marks, be careful not to reach into the engine compartment far enough to be injured by any of the moving components.
- Remember, the light makes the engine rotating parts look as if they are standing still, but they are still moving and dangerous!

- Make sure that the hood is secure with the hood stay rod.
- 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 make sure 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 working on.
- 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 supervisor.



Points to Note

- The timing light is a strobe light that is fired for a fraction of a second whenever the first spark plug fires inside the cylinder. When the light is pointed at the timing marks, the rapid sequence of flashes appears to freeze the engine in the same place on every stroke of the cylinder and consequent rotation of the crankshaft. This allows you to see clearly a special timing mark on the crankshaft pulley (or harmonic balancer) and where it is in relation to another mark on the engine. This will tell you whether the spark is firing at the correct time, or ahead or behind when it is supposed to fire. "Ahead" means the timing is "advanced" and "behind" means the timing is "retarded". In normal operation, advancing and retarding the ignition timing from the set point is desirable. However, this is controlled by the ignition system. It is not necessary for the technician to alter the timing from the manufacturer's specifications. In some cases, serious damage could result.

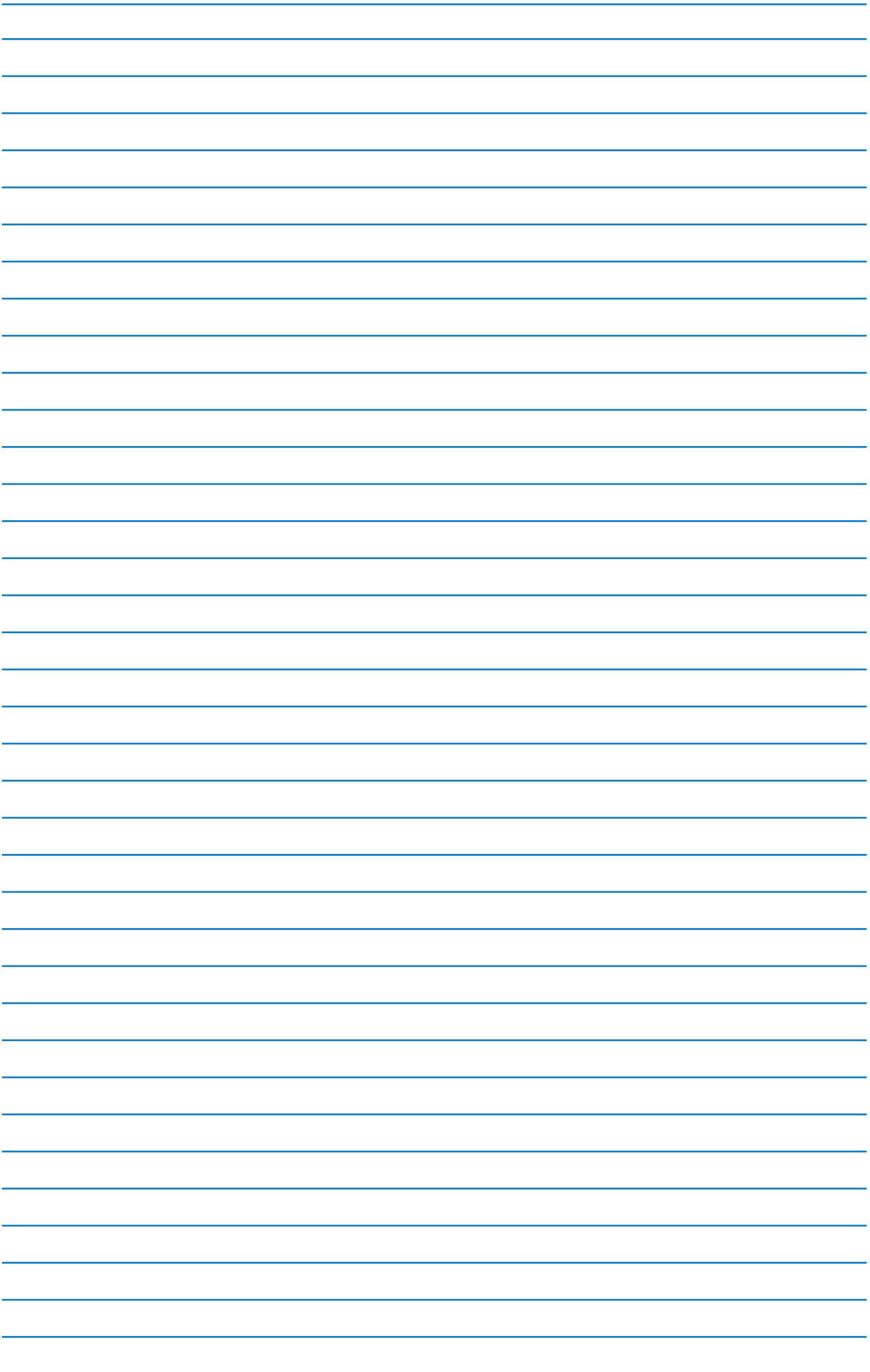
- Different manufacturers number their cylinders from different ends of the engine, so check the workshop manual if you are not sure where the number one cylinder is.

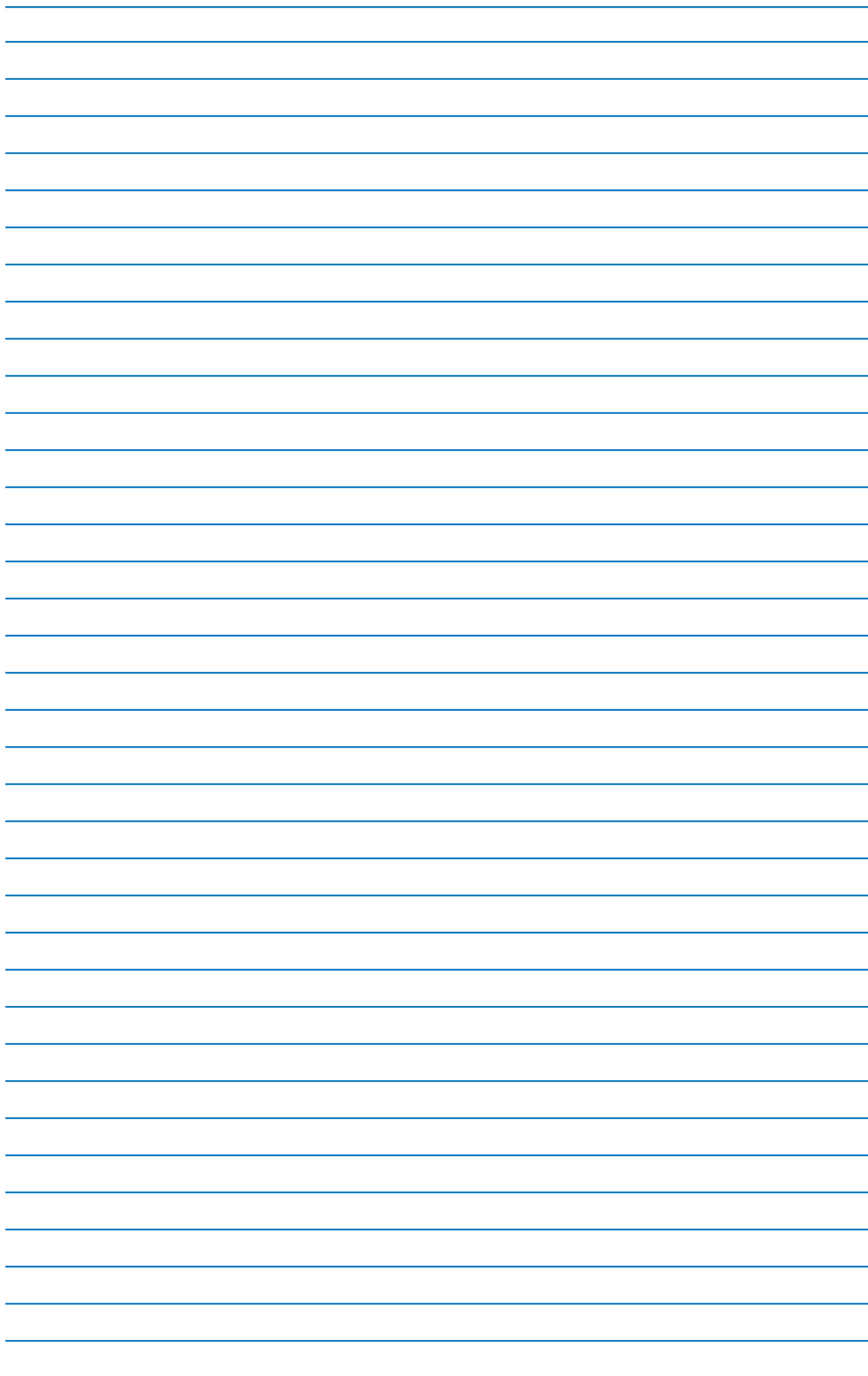
Step-by-Step Instruction

1. *Locate crankshaft and spark plug:* Locate the position of the timing marks. These are normally on the front of the engine on the crankshaft pulley or harmonic balancer, with a corresponding mark on the engine block. Locate the number one cylinder spark plug. If you are not sure which is the number one cylinder, refer to the workshop manual.
2. *Connect timing light:* Attach the timing light cable on to the High Tension Lead leading to the number one cylinder. Then connect the power leads to the battery – red lead to the positive terminal, black to the negative terminal.
3. *Check position of the timing mark:* Start the engine and point the timing light at the timing marks. Be careful not to touch any of the moving or hot components in the engine compartment. Note where the timing mark on the rotating crankshaft appears to be in relation to the stationary reference mark at engine idle speed. Compare this with the specification in the workshop manual. Rev the engine briefly to about 2500rpm. And note the position of the timing mark again. The timing should have advanced. If it does not, this could indicate a problem. Switch off the engine and detach the light cable. Report to your supervisor any reading, which is outside the specification.

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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