Pathfinder Honour:

Trainer's Notes

Small Engines

Instructions to Trainers / Instructors of this Honour

Thankyou for being involved with this Honour. These notes have been developed to assist in teaching / instructing this honour. We recognise that there is much more information available and we are grateful that you should share your expertise.

Please remember that Honours are designed to develop our Pathfinders in many ways; their interests, their knowledge and their relationship with their Saviour and Creator. Your enthusiasm and creativity will have a huge impact on those doing the honour.

To complete an Honour, the following (where applicable) must be completed satisfactorily:

- Physical and Practical Requirements.
- Honour Workbook.
- Honour Assessment Sheet. *(On SPD Honour Website but Leader's level access is required)*

Additional Reference Material

Please refer to text of these notes for additional reference material.

Acknowledgements

David McCrostie, Damien Ridley, Tasmanian Conference (Initial Draft of these Notes)
Wikibooks: http://en.wikibooks.org/wiki/Adventist_Youth_Honors_Answer_Book/Vocational/Small_Engines
This site provided much useful material for the updated layout of this honour, but be aware that material on any Wikibooks site is beyond the control of the SPD.

Please refer to the text of these notes for further citations.

Small Engines Honour

INTRODUCTION

The objective of this honour is to give participants a basic understanding of small engines. It focuses only on the basic concepts and does not delve into the complexities of computerised engine-management systems or design innovations associated with high-performance engines such as found in modern motorcycles.

REQUIREMENT 1: **Describe the basic design and operation of the 2 stroke (2-cycle) engine and the 4-stroke (4-cycle) engine.**

The best way to understand the 2-stroke and 4-stroke engines is to see a cut-away or dismantled engine going through its cycles of operation.

There are a number of websites which offer a video explanation:

- Two Stroke presentation: A good description of basic principles.
  http://www.youtube.com/watch?v=MW1jixDvUSY
- Two Stroke presentation - Basic principles
  http://www.youtube.com/watch?v=LuCUmQ9FxMU
- Two Stroke and four stroke presentations
  http://www.youtube.com/watch?v=GwFB3RcVcHI&NR=1

In addition, the following sites offer an animated version of the cycles:

- Animated engines:
  http://www.animatedengines.com/index.shtm
- Animated 2 Stroke engine cycle:
  http://commons.wikimedia.org/wiki/File:Two-Stroke_Engine.gif

Two Stroke Cycle

The following diagrams and accompanying, adapted text have been sourced from:
http://www.dukesofwindsoar.com/dukes.cgi?do=html&htmlfile=html/ppg_info/runningtwostrokeengine.html

A two-stroke in its basic form is extremely simple in construction and operation, as it only has three primary moving parts - the piston, connecting rod, and crankshaft. In small engines (lawn mowers, brush cutters, chainsaws etc) it is usual to have only one cylinder in which a piston goes ‘up and down’.

The operating cycle of a single-cylinder two-stroke engine is as follows.
Spark plug fires
Piston goes ‘down’ (one stroke ie first stroke)
Piston comes back ‘up’ (one stroke, ie second stroke),
Spark plug fires,
Piston goes down

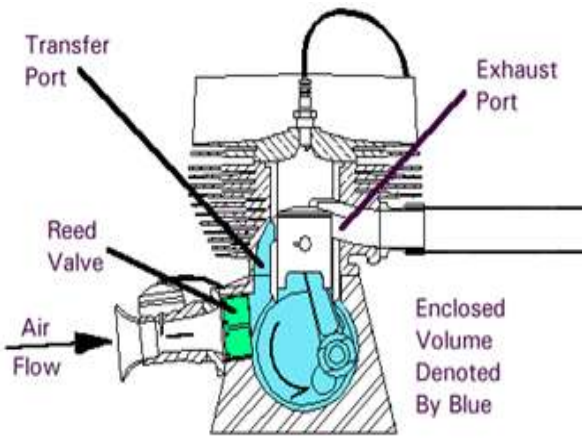
In understanding a two-stroke engine cycle it is important to remember that, when the engine is running, **there are gases above the piston** (where the spark plug is) **and gasses below the piston** (ie the crankcase) **AT ALL TIMES.** Above the piston, combustion takes place. An air / fuel mixture is first drawn into the engine below the piston.

The easiest way to visualize two-stroke operation is to follow the flow of gases through the engine. In this case, the cycle begins at approximately mid-stroke when the piston is rising, and has covered the transfer (ie inlet) port openings.

Don't worry about the gases above the piston at this stage. *Let's look at what is happening below the piston*.

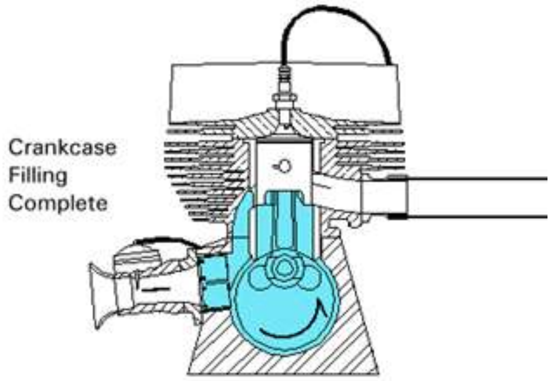
As the piston moves upward, a vacuum is created beneath the piston in the enclosed volume (coloured blue) of the crankcase.

Air flows through the carburettor creating a fuel vapour which enters through the reed valve (on the left of diagram) to fill the vacuum created in the crankcase.



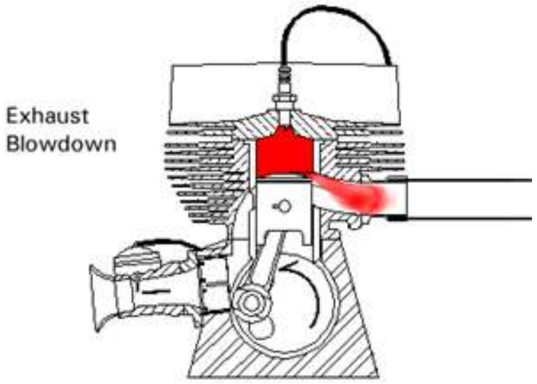
The piston continues its travel towards the top of the cylinder. The crankcase is now filled with air / fuel mixture (coloured blue).

Now let's shift our attention to what is happening above the piston. See the next diagram.



Just as the piston reaches the top of the cylinder, the spark plug ignites the air / fuel mixture (coloured red). Note that THIS MIXTURE WAS PROVIDED BY THE PREVIOUS CYCLE

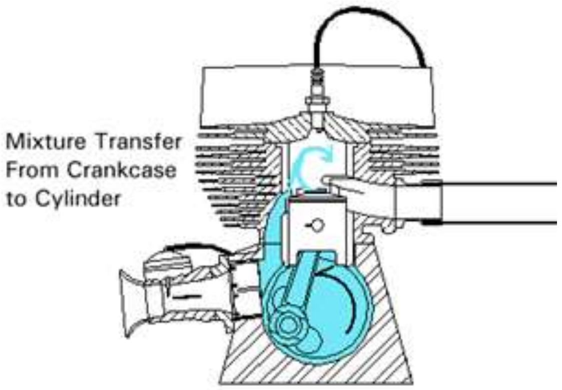
The sudden expansion of hot gasses forces the piston down until the exhaust port is exposed allowing the exhaust gases to escape into the exhaust system.



Let's return our attention to what is happening below the piston.

During the down stroke, the 'falling' piston creates pressure in the crankcase which causes the reed valve to close.

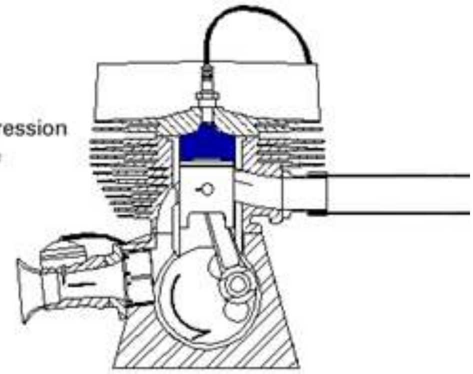
The mixture in the crankcase is compressed until the piston uncovers the transfer (ie inlet) port openings, at which point the mixture flows up into the top of the cylinder. The sudden entry helps displace some of the remaining exhaust gases from the previous cycle.



Mixture transfer continues until the piston rises high enough to shut off both the inlet and exhaust transfer ports.

The trapped mixture is now compressed (coloured dark blue) by the upward-moving piston

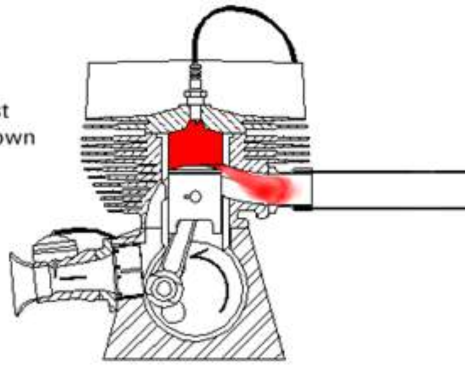
Note. At the same time a new charge is being drawn into the crankcase below the piston to be used in the next cycle. This is not shown in this diagram



Just as the piston reaches the top of the cylinder, the spark plug ignites the compressed air / fuel mixture (coloured red). .

The sudden expansion of hot gasses forces the piston down until the exhaust port is exposed allowing the exhaust gases to escape.

. . . and so the next cycle begins.

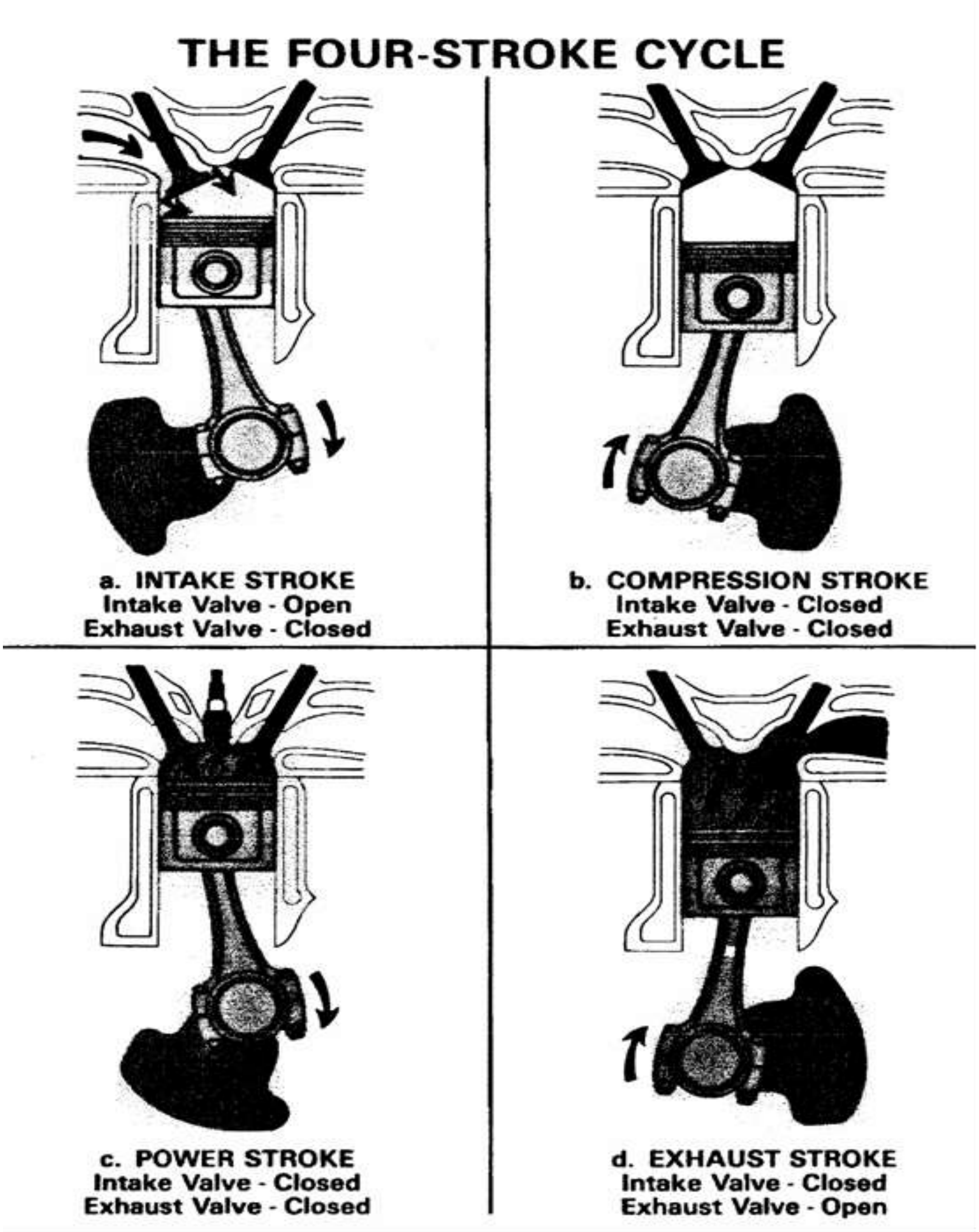


Four Stroke Cycle

A four-stroke engine is so named because it requires four strokes to generate power. There are some significant differences between typical 2-stroke and 4-stroke small engines. Of course, given the diversity of these small engines, the following comparisons are only general in nature. One would expect to find these small 4-stroke engines powering mowers, small generators, small pumps etc

- For a 2-stroke engine, there is a power strike every revolution, whereas for a 4-stroke there is a power stroke every <u>two</u> revolutions.
- A 2-stroke engine is a simpler design; having about three moving components, whereas a 4-stroke has at least 13. This tends to make a 2-stroke engine lighter and cheaper to manufacture than a 4-stroke of equivalent power.
- Most small 2-stroke engines require oil to be mixed with the fuel for lubrication, whereas a 4-stroke engine recirculates oil in a reservoir (ie sump).
- A 2-stroke engine can be operated on any angle (providing fuel can be supplied to the engine); however the tilt of a 4-stroke engine is limited because the oil level of the sump is lowered as the engine tilts. The suction pipe or the oil pump may come out of the oil with loss of lubrication resulting in permanent damage to the engine.
- A 2-stroke engine generally uses more fuel per kilowatt than a 4-stroke engine.
- A 2-stroke engine generally emits a greater level of exhaust pollutants; mainly because of the engine design (ie ports) and oil in the fuel for lubrication.

An explanation of the 4-stroke engine cycle is provided overleaf. The figure is from the SPD Small Engine Honour Notes, while the text is from Wikibooks: http://en.wikibooks.org/wiki/Adventist_Youth_Honors_Answer_Book/Vocational/Small_Engines



a. <u>Intake Stroke</u>: During this stroke the piston moves down in the cylinder. This creates a vacuum, drawing air through the carburettor, and sending the mixture of air and fuel into the cylinder. The air and fuel enters through the intake valve which opens at the beginning of this stroke.

b. <u>Compression Stroke</u>: Once the air and fuel have been drawn into the cylinder, the intake valve closes and the piston returns towards the engine's head. This compresses the fuel.

c. <u>Power Stroke</u>: When the piston reaches the top of the cylinder (just before Top Dead Centre ie TDC), the spark plug fires, igniting the compressed air-and-fuel mixture and causing an explosion. This explosion causes the gases to expand and power the piston downwards again. This is where the engine's power comes from.

d. <u>Exhaust Stroke</u>: When the piston reaches the bottom of the cylinder, the exhaust valve opens and, as the piston returns to the top of the cylinder again, the exhaust gases are pushed out. When the piston reaches the top again, the four cycles are ready to repeat.

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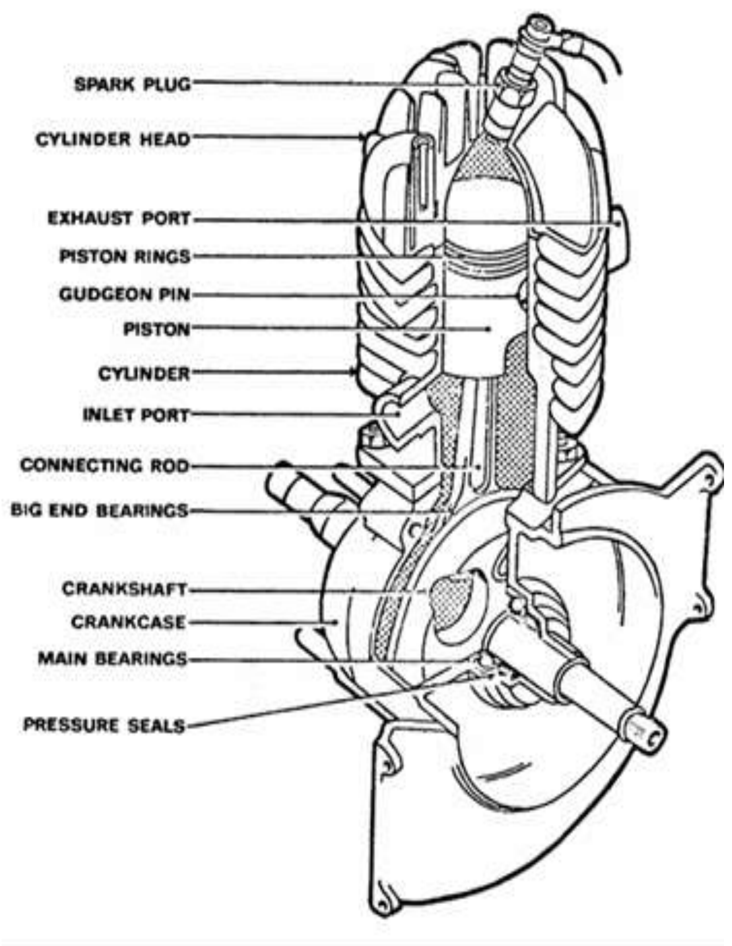
REQUIREMENT 2: Name the parts of the 2-stroke (2-cycle) engine and tell what each part does.



Shown in diagram

Spark Plug: It produces an electrical spark igniting the air/fuel mixture as the piston reaches the top of the cylinder.

Cylinder Head: The part into which the spark plug screws.

Exhaust Port: The hole in the cylinder wall through which the burnt fuel (exhaust) is expelled.

Piston: The piston travels up and down inside the cylinder. Its downward motion is propelled by an explosion of air and fuel ignited by the spark plug.

Piston Rings: 'Rings' attached to the piston to seal the bore of the cylinder to prevent gasses passing.

Cylinder: The space inside the engine block in which the piston moves. The contact surface is called the bore.

Inlet Port:(ie intake port) It is the passage-way between the crankcase and the cylinder through which the air / fuel mixture enters before combustion.

Connecting Rod (ie con rod): It connects the piston to the crankshaft.

Big End Bearings: Bearings on the connecting rod / crankshaft.

Crankshaft: The crankshaft converts the piston's up-and-down motion into rotary motion and transfers the engine's power to the outside of the engine.

Crankcase: The crankcase is the cavity in the engine block beneath the cylinder, and is where the crankshaft is. This is where fuel is drawn into the engine prior to being forced into the cylinder.

Not shown in diagram

Intake Valve (Reed valve): The intake valve opens to allow the air / fuel mixture to enter the crankcase during the piston's up-stroke, and closes to prevent its escape.

Flywheel: The flywheel is a mass attached to the crankshaft. It preserves the engine's momentum, keeping the crankshaft turning between the explosions in the combustion chamber. It also has a magnet in one side, which passes by the magneto, generating the electricity to fire the spark plug.

Magneto: The magneto sits next to the flywheel, and has a coil that acts like a generator when the magnet in the flywheel passes it. In older engines, the power from the magneto coil is switched by points, to control the timing of the spark. On newer engines, electronics are used.

Fuel Filter: It captures contaminants in the fuel, preventing them from entering the carburettor.

Carburettor: The carburettor is the device that mixes the air and fuel together prior to its being transferred into the engine.

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REQUIREMENT 3: List the fuel types used in small engines and explain their use.

Petrol – also called Gasoline
Petrol (Premium-Unleaded Petroleum or Unleaded Petroleum) is the most common fuel for 4-stroke small engines, especially those found on lawnmowers, fire fighting pumps, tillers, and other garden equipment.

Petrol/oil mixture - commonly called 2-stroke Petrol
Petrol/oil mixture is used in 2-stroke engines. The ratio of petrol to oil is usually in the range of 15:1 to 50:1. See the engine manufacturer's instructions. Two stroke engines are often found on smaller items such as chain saws and line trimmers. It can be supplied already pre-mixed. If mixing your own 2-stroke petrol, always put the 2-stroke-fuel oil in the container first. Then add the petrol. This ensures that the oil is mixed through the fuel.

Diesel – also called Dieseline
Diesel fuel is used in diesel engines. Although usually associated with larger equipment and motor vehicles, small diesel engines are used for rider mowers, small tractors, pumps and electric generators.

Nitro-methane
Nitro-methane is used for very small engines, such as those that power Radio Controlled model airplanes.

Note: Gaseous fuels such as LPG (Liquid Petroleum Gas) and CNG (Compressed Natural Gas) are commonly used on larger engines, but not in small engines. They are not required for this honour

REQUIREMENT 4: Know and demonstrate safety rules associated with the operation of small engines including care and safety in fuel handling and storage.

Always remember that small engines and their fuels have the potential to cause harm to people and property. Safety considerations consist of, but are not limited to, the following:

- Comply with all legislative requirements applicable to where the small engine/s will be operated.
- Read, understand and comply with the manufacturer's / supplier's instructions.

<u>When operating a small engine:</u>

- Always do the pre-start checks; sufficient fuel and lubricants, all components in good order etc.
- Do not operate an engine in a confined space because of the risk of the build up of lethal carbon monoxide.
- Do not operate an engine near flammable materials such as fuel, cloth etc.
- Ensure that no rotating or hot components come in contact with people or property.
- Ensure the engine is properly inspected & maintained (loose/leaking components).
- Use the engine only for what it was designed.

When handling or storing of fuel:

- Use only government-approved and properly maintained containers.
- When transporting containers, protect from damage during transit; for example chafing, being pierced by sharp objects or damaged by other parts of the load shifting.
- Do not fill the container more than 90-95% full to allow room for expansion if the container gets hotter.
- Place the fuel container on the ground and keep the fuel nozzle in constant contact with the container when filling it.
- Do not leave it in a car or in the back of a vehicle. This will reduce the risk of the build-up of static electricity which can ignite the fuel.
- Do not store a fuel container in the boot of a car, in direct sunlight, or near an open flame or source of sparks.
- Never add fuel to, or open the filler cap on-or-near a running engine.
- Ensure an engine has cooled down before removing the fuel cap or adding fuel.
- Keep the container's nozzle in constant contact with the fuel tank when adding fuel to the engine.
- Do not allow anyone to smoke within 15 metres of an open fuel tank.
- Remove any spilled fuel after fuelling an engine and allow any remains to evaporate before starting the engine.

The rules listed above rightly focus in preventing harm to people and property. It is strongly recommended, however, that thought be given on what to do if something goes wrong. It only needs to be as complicated as the situation warrants.

In addition to this, consideration needs to be given to care of the natural environment. This is especially applicable to disposing waste.

REQUIREMENT 5: Describe two types of ignition systems used in small engines.

With the development of microelectronics, there is a continual sophistication in the application of ignition systems on small engines, particularly in the high performance category. The following notes give an overview of the topic.

Magneto Ignition

The simplest form of spark ignition is that using a magneto. A battery is not needed.

The engine spins a magnet (normally cast into the outer edge of the flywheel) past a coil. Also rotating with the crankshaft is a small camshaft which opens the contact breaker called "points" just before the piston reaches top-dead-centre before the power stroke. This interruption of the current creates a very high voltage in the magneto coil which is connected to the relevant spark plug via spark plug lead.

Magnetos are not used in modern cars, but because they generate their own electricity, they are often found on small engines used for lawnmowers, line trimmers, chainsaws, etc.

Battery Ignition

Battery ignition systems use electricity from a battery which is recharged by the engine's alternator. This system is more common in multi-cylinder engines. The battery is also be used to start the engine.

Battery systems are capable of delivering sparks to multiple cylinders which are selected by a rotor in the distributor. The advantage of a battery ignition system is that the timing of the spark may be automatically adjusted by the engine to increase its efficiency based on how fast it is running.

Older systems used mechanical methods to create the high-voltage spark and to alter the timing of the spark. Modern electronic ignition systems use sensors on the engine to monitor engine operating conditions and the spark timing / profile is adjusted accordingly.

Compression Ignition

Compression ignition applies to diesel engines and some tiny model-aircraft engines. On the compression stroke, the air in the cylinder becomes very hot as maximum compression occurs towards top-dead-centre. In a diesel engine, a diesel fuel charge is injected under very high pressure and it 'burns' instantaneously. The expanding gasses drive the piston down on the power stroke.

Glow Plug Ignition

Glow plug ignition is used in the combustion zone of some diesel engines or small-simple engines such as those used for model aircraft. A glow plug is a coil of special wire that glows red hot when an electric current is passed through it. This aids combustion, especially during the initial start-up. On diesel engines, it is turned off once the engine is running. On the small-simple engines, the coil retains sufficient residual heat due to the heat generated on the previous stroke. This aids combustion.

REQUIREMENT 6: Describe acceptable cleaning products for small engines and engine parts. Why is gasoline (ie petrol) considered an improper cleaning fluid?

Before you start, it is recommended that you check the properties of the various cleaning products available for cleaning engines and engine parts. In Australia, manufacturers / suppliers are required to compile a Material Safety Data Sheet (MSDS) for each product. These may be requested from the supplier or alternatively downloaded from the internet. A MSDS provides information on composition, toxicity, use, storage, disposal, environmental requirements etc

<u>Mineral Spirits</u> and their derivatives have traditionally been used for cleaning parts. Soaking parts in a bath of mineral spirits removes most oils and greases, usually without the need for vigorous scraping and scrubbing. Once the parts are removed from the bath, the mineral spirits quickly evaporate.

<u>Environmentally Friendly Alternatives</u>: There are many degreasers on the market today, and many of them are billed as "environmentally friendly." Many contain limonene in various forms. Various claims of biodegradability and non-toxicity are made.

<u>Petrol is not recommended</u> as it extremely flammable and dangerous to work with. It is also a carcinogen (cancer-causing agent), so prolonged contact with it should be avoided. It can also damage plastic parts. It also has many additives, some of which stay on the part after it has been cleaned. They also soak into your bloodstream.

REQUIREMENT 7: List and tell how three basic lubrication systems operate.

Oil-in-Fuel System

This system is common in small 2-stroke engines. The oil may be premixed (fuel ratio from 15:1 oil to 50:1 oil) or injected. Engine parts are lubricated as the turbulent fuel gases swirl around the engine components

Splash Systems

In a splash lubrication system, dippers on the crankshaft are repeatedly submerged and lifted out of the oil in the oil pan (ie sump). This happens as the crankshaft turns. When the dippers emerge from the oil bath, oil is splashed all about the inside of the chamber where it finds its way to the pistons, rods, and other moving parts.

Pressurized Lubrication Systems:

In a pressurized lubrication system, an oil pump sucks oil from the oil pan (ie sump) and forces it through a filter and then on through a system of passageways drilled into various parts of the engine. These passageways are called galleries. The galleries open to spurt the oil onto critical components such as the bearings, gears and valve assemblies.

Combination Splash/Pressure Systems

As the name suggests, a combination splash/pressure lubrication system is a combination of the two systems described above. The connection between the rod and the piston, as well as the cylinder walls, are lubricated using the splash method. The main crankshaft bearings, as well as the camshaft, rocker arms, Etc. are lubricated by the pressurized system.

Dry Sump

The dry sump lubrication system is similar to the pressurized lubrication system. However, there is no oil in the oil pan. It is all stored in a remote, pressurized reservoir and then fed to the engine by the oil pump.

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REQUIREMENT 8: List a general trouble-shooting procedure for small engines.

All engines require sufficient compression to efficient operation. This is readily felt on manual-start engines, but a compression gauge is required for battery-start models. The following checklist focuses on an engine which can be 'turned over', but not started.

It follows the acronym FAST - Fuel, Air, Spark, and Timing.

Fuel

Objective: Make sure fuel (or the correct amount) is getting into the combustion chamber.

- ☐ The most obvious. Check there is sufficient fuel (and the correct fuel type) in the tank and that the fuel cock (if fitted) is turned on.
- ☐ If the fuel requires priming (common on small 2-strokes), make sure this is done.
- ☐ Check that the fuel filter / strainer is not clogged or there is no water in the fuel.
- ☐ Check the fuel lines are not damaged or kinked and that they are correctly installed.
- ☐ If the engine has a fuel pump, make sure it is operating correctly
- ☐ Check to see if the engine is not flooded. This means that it has too much fuel in the carburettor. Symptoms are leaking fuel or the smell of fuel. If so, let it sit for a while. Then open the choke and, at full throttle, try starting it again.
- ☐ A problem with some small engines - especially after they have been sitting for a while - is for the carburettor to get clogged, have the diaphragms get old and stiff, or have needle and seats sticking or leaking. A rebuild kit may be required.

Air

- ☐ Make sure the choke is adjusted properly. On an engine with a manual choke, close the choke all the way and open up the throttle. Then try to start it. If it doesn't start after a couple of pulls, open the choke halfway and try again. When the engine starts, open the choke over the next few seconds until the engine runs smoothly.
- ☐ If it still won't start, check that the air filter is not clogged.

Spark

- ☐ The most obvious. Check the engine is 'switched on' – a surprisingly common 'fault'.
- ☐ If the engine has a low-oil safety cut-out device, check that there is sufficient oil in the crankcase as this device cuts out the spark.
- ☐ Check that there is spark, and that it is a good strong blue spark.

  The simplest test is to detach the spark plug lead from the spark plug and hold it about 10mm from the metal of the engine while it is being cranked. Be careful not to touch the metal tip! The shock is unpleasant and it could cause serious injury, especially if you have a pacemaker.
- ☐ Check the spark plug/s. Dirty spark plugs are a common problem with oil-in-the fuel 2-stroke engines. Spark can be tested insitu by placing the spark plug terminal against the metal of the engine and cranking the engine. Alternatively a spark plug testing machine may be used. These machines often have a cleaning facility. The gap should also be checked. If in doubt, it is usually a good investment to replace the spark plug/s
- ☐ If there is still no spark, check for broken wires, poor connections, or faulty spark plug lead/s.
- ☐ If it is an older style engine with points, you may need to check both them and the condenser. Rain or moisture can cause problems. The points can get dirty or corroded, or just wear away. They are often behind the flywheel. Electronic ignition engines can have the module burn out.

Timing

- ☐ On small engines, the timing normally does not change. However, on certain engines (Briggs & Stratton for instance) the key holding the flywheel to the crankshaft may shear. This is a safety feature designed to protect other parts of the engine. When it shears, the flywheel turns on the crankshaft altering the timing. Check the flywheel for correct position.

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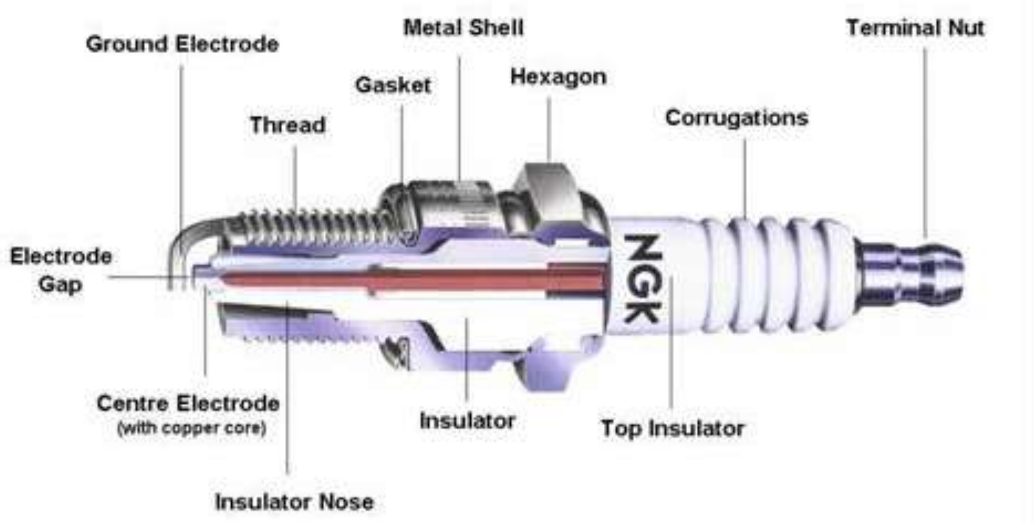
REQUIREMENT 9: Demonstrate that you know how to test and clean spark plugs and discuss how the examination of spark plugs gives an indication of the condition of a small engine.

Inexpensive spark plug testers (of unknown accuracy) are available from automotive suppliers. These need the engine to be running. Spark plug testing machines are also available and these machines both clean and test spark plugs.

If replacement spark plugs are readily available, it is generally worthwhile replacing them rather than worrying about cleaning / servicing them as is described below.

First, let's look at a typical spark plug. This diagram was sourced from the NGK Spark Plug Company. http://www.ngkspark.com.au/sparkplug.php#

The spark plug lead (ie high tension lead) is attached to the Terminal Nut end on the right of the diagram. The spark arcs across the Electrode Gap on the left of the diagram.



After removal from the engine, the first step is a visual check of the spark plug:

- ☐ Check the top insulator for signs of cracking, damage or misfiring (there often are faint black/brown arcing marks on the porcelain)
- ☐ Check the condition of the ground electrode and centre electrode for wear etc
- ☐ Examine the insulator nose for cracking or missing material.

A wire brush (or old toothbrush) can be used to clean spark plugs. (Don't use it to brush your teeth afterwards though!). Remove all carbon, soot and gunk build-up. Remove gunk from around the insulator nose using a pointy object.

For effective operation, the condition of the ground electrode and centre electrode should be as close as possible to the condition shown in the picture above. Some removal of material may be required.

Set the spark plug gap as per manufacturer's specification by moving the ground electrode closer or further from the centre electrode. Use a feeler gauge or gap gauge. Note that, if these are not available, a metal cutting blade from a hand hacksaw is a good approximation for most spark plug gaps.

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Examination of spark plugs to give an indication of the condition of a small engine.

The following notes were sourced from the NGK Spark Plug Company: http://www.ngksparkplugs.com/techinfo/spark_plugs/faq/faqread2.asp

The insulator firing nose colour and condition gives an indication of an engine's overall operating condition.

In general, a light tan/grey colour indicates that the spark plug is operating at optimum temperature and that the engine is in good condition. Dark colouring, such as heavy black, wet or dry deposits can indicate an overly-rich condition, too cold a heat-range spark plug, a possible vacuum leak, low compression, overly retarded timing or too large a plug gap.

Some conditions are shown as follows.

<u>Normal Condition</u>
If the firing end of a spark plug is brown or light grey, the condition can be judged to be good and the spark plug is functioning optimally.

<u>Normal Life</u>
A worn spark plug not only wastes fuel but also strains the whole ignition system because the expanded gap (due to erosion) requires higher voltages.

<u>Overheating</u>
When a spark plug overheats, deposits that have accumulated on the insulator tip melt and give the insulator tip a glazed or glossy appearance.

<u>Breakage</u>
Breakage is usually caused by thermal expansion and thermal shock due to sudden heating or cooling.

<u>Wet Fouling</u>
This is an indication of a very rich fuel mixture. The 'wet' look is an typical of flooding of the carburettor. If flooding the spark plug is likely to smell of petrol.

REQUIREMENT 10: Demonstrate that you can overhaul, clean, inspect, reassemble, and properly tune a small engine.

A competent instructor is recommended for this requirement.