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Internal Combustion Engine



Internal combustion engines were invented in the 1860s, but it was the German engineer Nikolaus August Otto who in 1867 patented the four-stroke “Otto” cycle engine that we use today.

Internal combustion engines are generally twice as efficient as “external combustion” engines, like the old steam engines.

The power of an internal combustion engine comes from carefully controlled burning of fuel inside the cylinder.

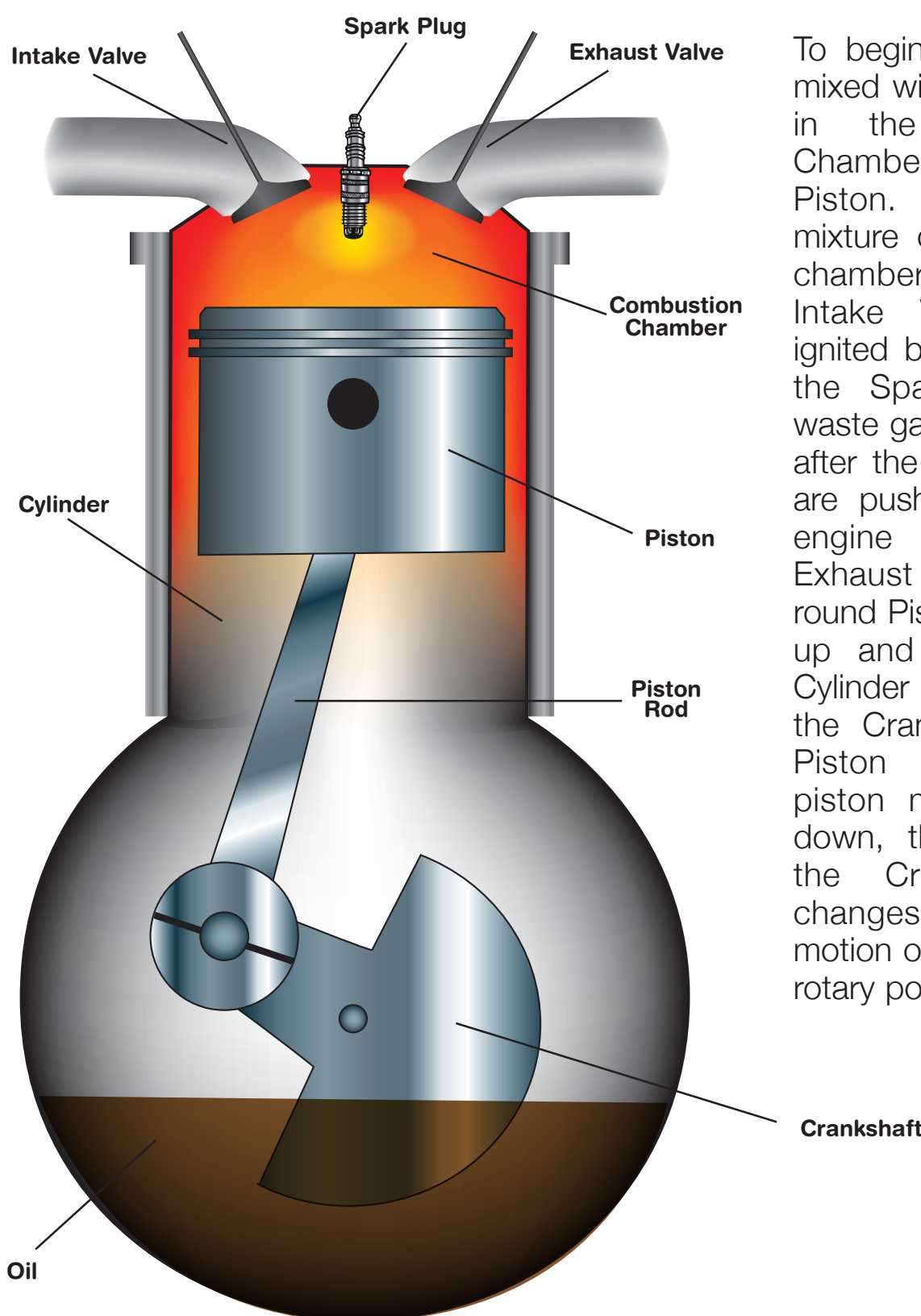
HOW A GAS ENGINE WORKS

INTERNAL COMBUSTION

The Motor-Works model shows the basic parts of a four cycle internal combustion gasoline engine. This is the most common type of gasoline engine and is the kind used in most cars and trucks.

The power of an internal combustion engine comes from the carefully controlled burning of fuel inside the cylinder. That’s why it’s called an “internal combustion” engine – it literally means “burning inside.” Internal combustion engines are generally about twice as efficient as “external combustion” engines, like the old steam engines.

Internal combustion engines were invented in the 1860s, but it was the German engineer Nikolaus August Otto who in 1867 patented the four-stroke “Otto” cycle engine that we use today. This is the kind of engine shown in the Motor-Works model. All “four-stroke” engines work in the same way and have the same basic parts inside. These are shown in the drawing.



Understanding how these parts work will let you understand the basic principles of all engines.

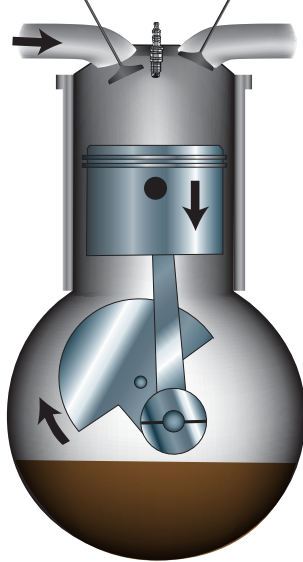
To begin with, gasoline mixed with air is burned in the Combustion Chamber above the Piston. The gas/air mixture comes into the chamber through the Intake Valve and is ignited by a spark from the Spark Plug. The waste gases that remain after the gasoline burns are pushed out of the engine through the Exhaust Valve. The round Piston that moves up and down in the Cylinder is connected to the Crankshaft by the Piston Rod. As the piston moves up and down, the “rod” turns the Crankshaft and changes the up/down motion of the piston into rotary power.

THE FOUR CYCLES

The four cycles – or “strokes” – of an engine are “**Intake**”, “**Compression**”, “**Power**” and “**Exhaust**”. These repeat again and again in the same order as the piston moves up and down in the cylinder. Since most engines have more than one cylinder, these cycles are alternated in the different cylinders to reduce vibration and make the engine run smoother.

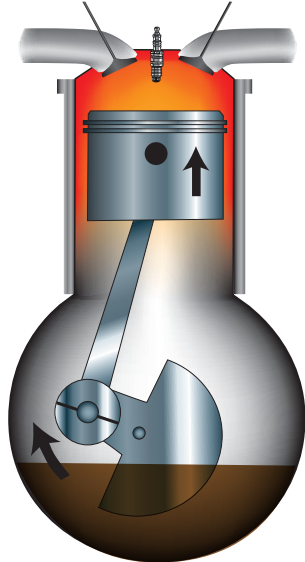
In the **Intake** stroke, the piston is descending and the Intake Valve is open. Since the piston is tightly sealed against the walls of the cylinder, it pulls the gas/air mixture into the cylinder behind it.

1
INTAKE



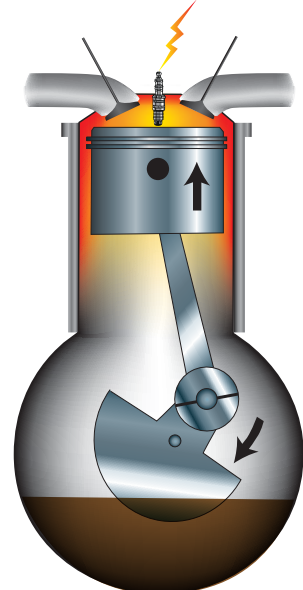
In the **Compression** stroke, the piston has gone down as far as it can and is now moving back up. Both valves are closed, so the gas has no place to go and is “compressed” by the piston.

2
COMPRESSION



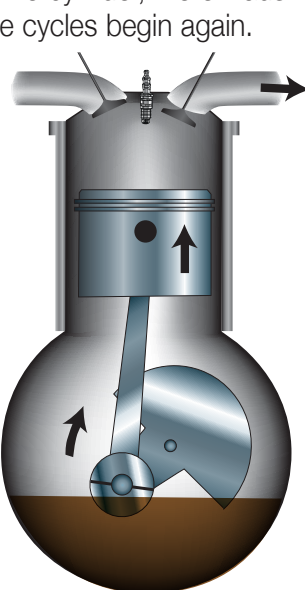
In the **Power** stroke, the piston has just reached the highest point it can travel when the spark plug ignites the fuel. The gas literally explodes and pushes the piston rapidly down. This provides the engine’s power.

3
POWER



In the **Exhaust** stroke, the piston has again gone as far down as it can and is now moving back up. The exhaust valve is open and the piston pushes the “exhaust” gases out of the cylinder as it rises. As soon as the piston reaches the top of the cylinder, the exhaust valve closes, the intake valve opens and the cycles begin again.

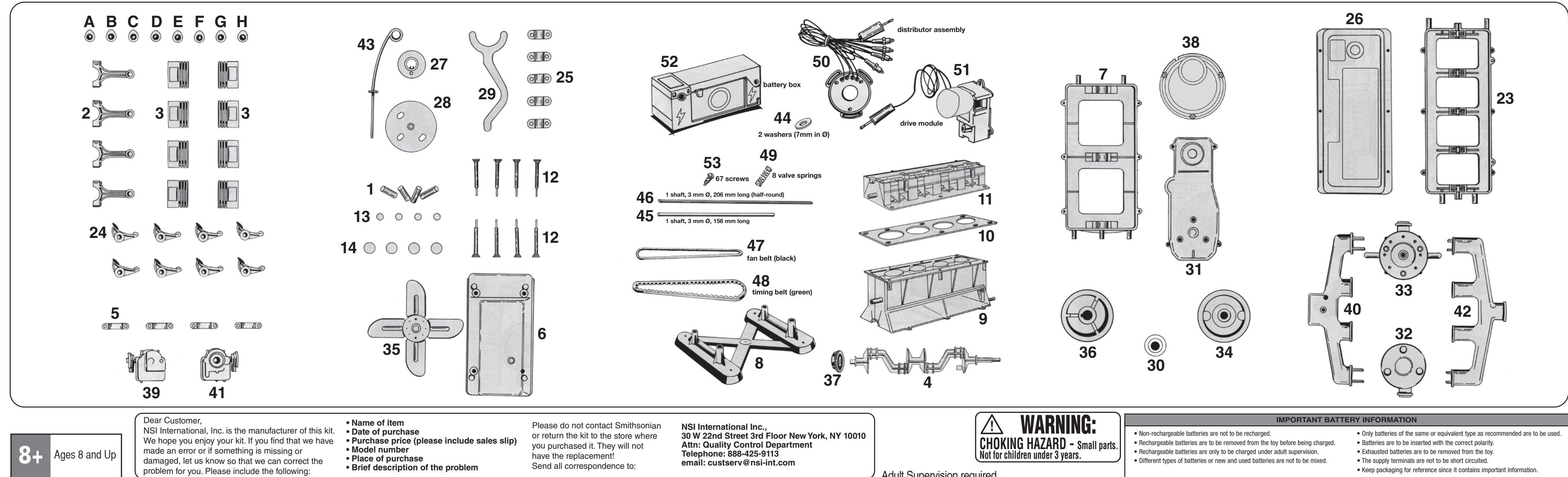
4
EXHAUST



Motor-Works™

Smithsonian® MOTORWORKS™

ITEM # 49013



8+ Ages 8 and Up

Dear Customer,
NSI International, Inc. is the manufacturer of this kit. We hope you enjoy your kit. If you find that we have made an error or if something is missing or damaged, let us know so that we can correct the problem for you. Please include the following:

- Name of item
- Date of purchase
- Purchase price (please include sales slip)
- Model number
- Place of purchase
- Brief description of the problem

Please do not contact Smithsonian or return the kit to the store where you purchased it. They will not have the replacement! Send all correspondence to:

NSI International Inc.,
30 W 22nd Street 3rd Floor New York, NY 10010
Attn: Quality Control Department
Telephone: 888-425-9113
email: custserv@nsi-int.com

WARNING:
CHOKING HAZARD - Small parts.
Not for children under 3 years.

Adult Supervision required.

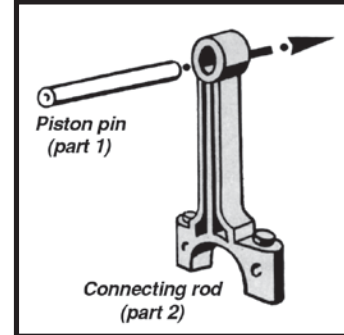
- IMPORTANT BATTERY INFORMATION**
- Non-rechargeable batteries are not to be recharged.
 - Rechargeable batteries are to be removed from the toy before being charged.
 - Rechargeable batteries are only to be charged under adult supervision.
 - Different types of batteries or new and used batteries are not to be mixed.
 - Only batteries of the same or equivalent type as recommended are to be used.
 - Batteries are to be inserted with the correct polarity.
 - Exhausted batteries are to be removed from the toy.
 - The supply terminals are not to be short circuited.
 - Keep packaging for reference since it contains important information.

DESCRIPTION	Number
8 timing cams	A-H
4 piston pins	1
4 connecting rods	2
8 piston halves	3
1 crankshaft	4
4 connecting rod keepers (big end)	5
1 oil-pan	6
1 lower crankcase	7
1 engine mounting stand	8
1 cylinder block	9
1 head gasket	10
1 lower cylinder head	11
8 valve stems	12
4 exhaust valves	13
4 intake valves	14
1 upper cylinder head	23
8 rocker arms	24
5 bearings	25
1 rocker arm cover	26
1 timing gear	27
1 timing wheel	28
1 positioning jig	29
1 belt tensioning pulley	30
1 timing belt cover	31
1 rear half of water pump	32
1 front half of water pump	33
1 fan pulley	34
1 fan	35
1 crankshaft pulley	36
1 flywheel clutch	37
1 clutch housing	38
1 carburetor bowl	39
1 intake manifold	40
1 carburetor cover	41
1 exhaust manifold	42
1 dipstick	43
2 washers, 7 mm ø	44
1 shaft, 3 mm ø, 156 mm long	45
1 shaft, 3 mm ø, 206 mm long (half round)	46
1 fan belt	47
1 timing belt (green)	48
8 valve springs	49
1 distributor assembly	50
1 drive module	51
1 battery pack	52
67 screws	53

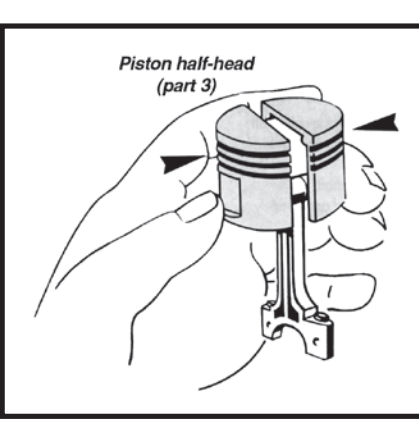
Requires 2 (1.5V) "AA" Batteries and screwdriver (Not Included.)

1 Assembling the pistons

Insert a piston pin (part 1) through the small end of the connecting rod (part 2).

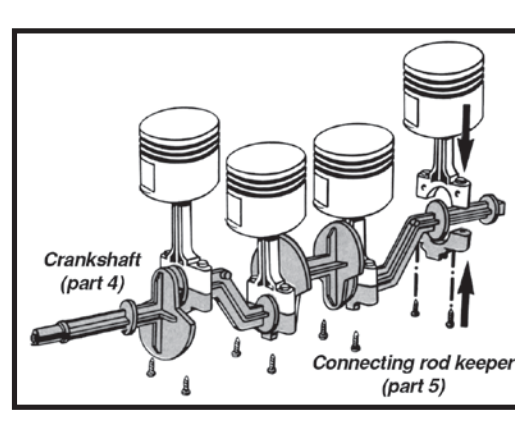
**2**

Fit two piston half-heads (part 3) onto the piston pin. Join the piston half-heads by pressing firmly against the sides. They should be solidly connected, and the piston should be able to rotate freely around the piston pin. Repeat operations 1 and 2 to assemble the other three pistons.

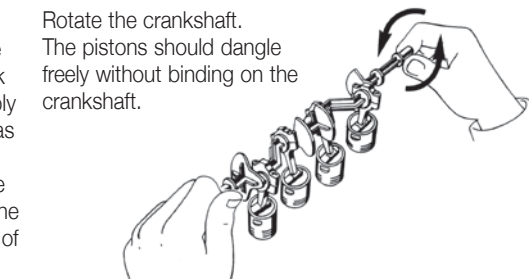
**3 Mounting the pistons on the crankshaft**

NOTE!
1. Break off the small tongue (marked with a '4') on the crankshaft prior to making the following assembly. Any remaining burrs could subsequently hinder rotation of the crankshaft, so trim them off with a knife. Adult participation is recommended when trimming.
2. Before screws, need to match the male/female flanges for connecting rods (part 2) and connecting rod keepers (part 5).

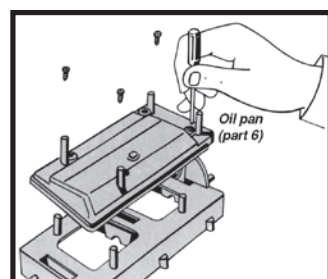
On the crankshaft (part 4) and on the drawing, identify the four locations at which the piston/ connecting rod assembly will be mounted. At each location, attach the big end of the connecting rod to the crankshaft by means of two screws through the keeper (part 5).

**4**

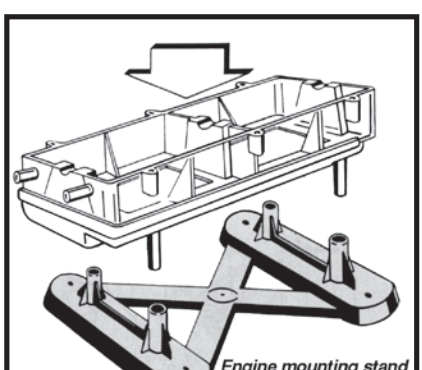
When all four piston/ connecting rods have been mounted, check the complete assembly for proper operation as follows:
Grasp the ends of the crankshaft between the thumb and forefinger of each hand.

**5 Mounting the oil pan on the lower housing**

Set the oil pan (part 6) on the four lugs protruding from the bottom of the lower crankcase (part 7), as shown in the drawing. Secure the oil pan using four screws.

**6**

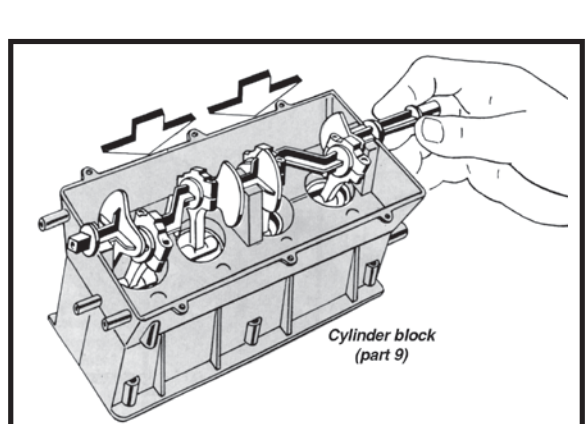
Insert the four mounting studs on the bottom of the lower crankcase/oil pan assembly into the matching receptacles on the engine stand (part 8).

**7 Installing the piston-crankshaft assembly in the cylinder block**

Position the piston-crankshaft assembly and the cylinder block (part 9) as shown in the drawing. Carefully insert the four piston heads into their respective cylinders in the cylinder block.

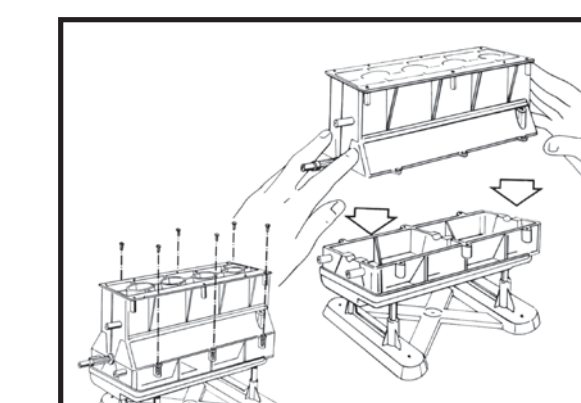
(Pay close attention to the drawing.)

SPECIAL NOTE: Pay close attention to the three screw posts. They need to be on the left side.

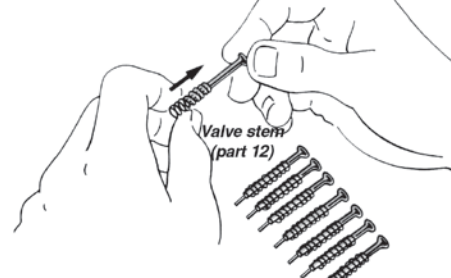
**8 Mounting the cylinder block assembly on the lower crankcase**

Position the oil pan/lower crankcase/engine mounting stand assembly as shown in the drawing. Grasp the ends of the crankshaft/ cylinder block assembly with the fingers of each hand, as shown by the drawing. Turn the assembly upside down so it is positioned as shown in the drawing. Set the cylinder block

assembly on the lower crankcase unit. Make sure the units are aligned as shown in the drawing, and that you have not reversed the orientation of either unit (lower crankcase and cylinder block studs should stick out to your left.)

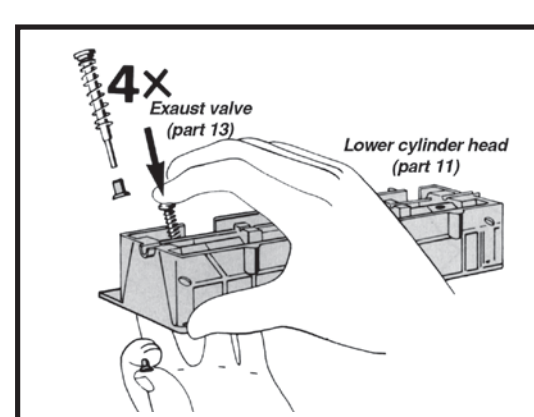
**10 Installing the springs on the valve stems**

Slide the spring over each of the eight valve stems (part 12).

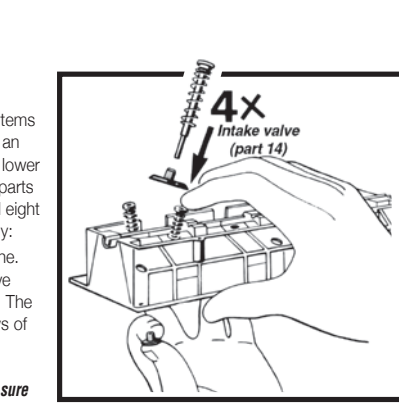
**11 Installing the valves in the cylinder head**

Position the lower cylinder head (part 11) as shown in the drawing. Locate the small holes. These are the holes for the exhaust valves. First, insert the ends of four valve stems in these holes, one by one (the springs are too large to slip through the holes). Now repeat the following operations for each of the four valve stems:
• Using your finger, press down on the upper end of the valve stem to compress the spring.

The other end of the valve stem will now be exposed below the cylinder head.
• Press the exhaust valve (part 13-the small ones) onto the lower end of the valve stem.
• Press firmly so the two parts will remain locked together.

**12**

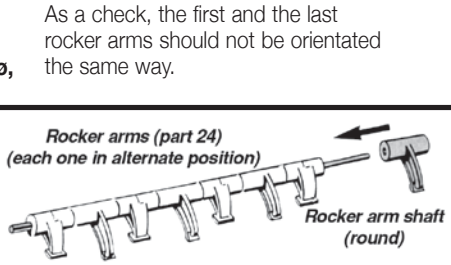
In the same manner, install the other four valve stems (and springs), this time in the large holes. Press an intake valve (part 14-the large ones) onto the lower end of each valve stem. Press firmly so the two parts will remain locked together. Check to see that all eight of the valves you have just installed work properly. Press on the spring end of each valve, one by one. The valves should open and close their respective holes as you press and release each valve stem. The action should be smooth, somewhat like the keys of a piano.



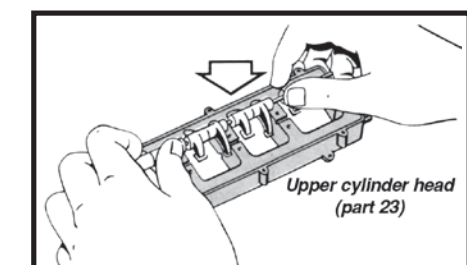
NOTE: Upper cylinder head has a small cover. Make sure it is in place, otherwise the valves will fall through.

13 Mounting the rocker arms on the rocker arm shaft

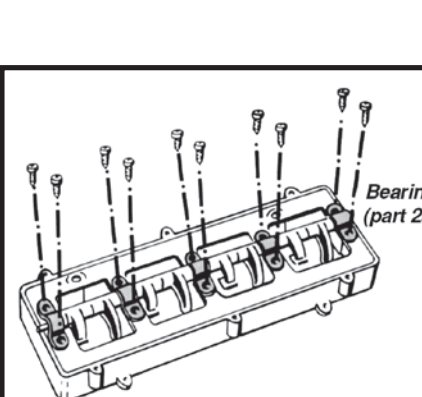
Collect the eight rocker arms (part 24) and the rocker arm shaft (round shaft, 3 mm in ø, 156 mm long). Slip each rocker arm onto the shaft, one by one. Rotate every other rocker arm 180° so that the long and short segments of each arm alternate (see diagram).

**14 Installing the rocker arm assembly in the upper cylinder head**

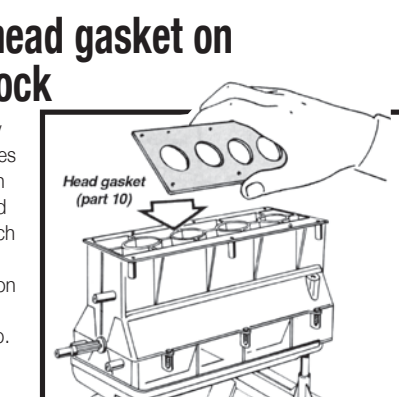
Hold the rocker arm unit that you have just finished assembling (step 13) over the upper cylinder head (part 23). Carefully slide the rocker arm unit into position (see drawing). Two rocker arms go into each of the four openings. Use your fingers to separate the four pairs of arms. Each arm of these four pairs should have a different orientation.

**15**

Position the five bearings (part 25) as shown in the drawing. Attach them to the cylinder head by means of 10 screws. When finished, check that the rocker arms pivot freely around their common shaft.

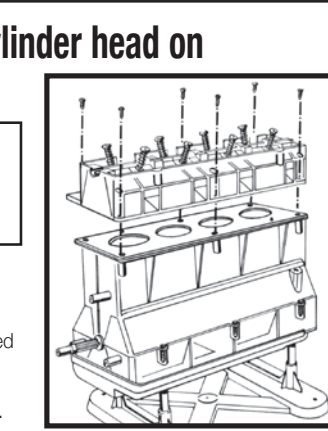
**16 Installing the head gasket on the cylinder block**

The head gasket (part 10) is attached by means of six screws passing through holes in the gasket: two at each end and two in the middle. There are also two holes used for alignment. Using a ballpoint pen, punch the cardboard out of these eight holes in the head gasket. Place the head gasket on the upper lip of the cylinder block. Note the two lugs protruding from the upper lip. They keep the head gasket in the correct position prior to final installation with the six screws. Use these lugs as a guide.

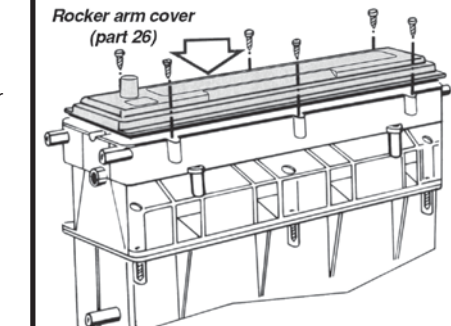
**17 Mounting the lower cylinder head on the cylinder block**

NOTE!
Before starting this step, carefully note the details shown in the drawing. This will help you properly orient the cylinder head.

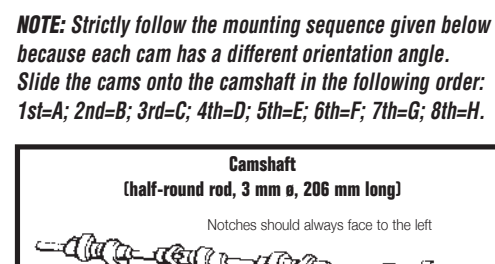
Position the lower cylinder head over the cylinder block. Prior to joining the two units make a final check on the orientation of the cylinder head and block. Note how the screws line up with the dashed lines on the drawing. When you are satisfied that everything is lined up properly, fasten the lower cylinder head to the cylinder block with six screws.

**21 Attaching the rocker arm cover**

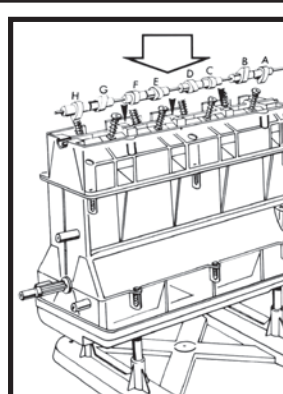
Place the rocker arm cover (part 26) over the upper cylinder head. Attach the cover to the upper cylinder head by means of six screws.

**18 Assembling the camshaft**

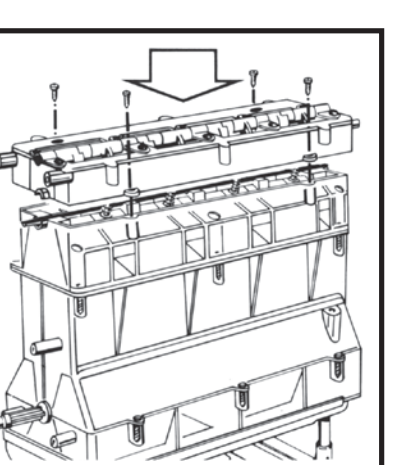
There are two ways you can identify the cams:
• Each cam is stamped with a letter (A-H)
• Each cam is marked with a line, the position of each line must correspond to the drawing.
Now, slide the cams on the camshaft (half-round shaft). The notch on Cam H (not shown) is on the back side.

**19 Installing the camshaft on the lower cylinder head**

First, make sure the splined (grooved) end of the camshaft is to your left. With the camshaft oriented as shown in the drawing (Cam H to your left), place the camshaft on the lower cylinder head. Each end of the camshaft is supported by grooves (bearings) in the lower cylinder head.

**20 Attaching the upper cylinder head to the lower cylinder head**

Place the upper cylinder head/rocker arm unit (assembled in step 15) over the lower cylinder head/camshaft unit (assembled in step 19). Check the orientation of the two units carefully. The screw holes in the two units must line up.

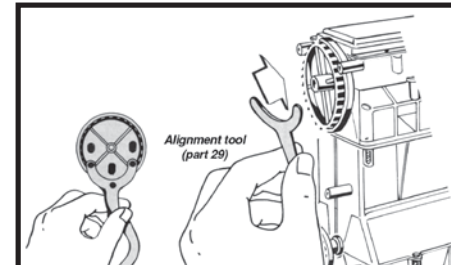


NOTE!
Before attaching the upper cylinder head with screws, you should check that the rocker arms are correctly positioned over the top of the valve stems. The way to do this is to actuate each rocker arm with your finger. The arms should push against the valves. Take care not to pull on the ends of the camshaft. Otherwise, the cams may shift their position and you will have to realign them again.

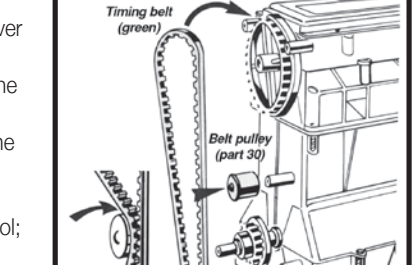
When you are satisfied that everything is properly positioned, attach the upper cylinder head to the lower cylinder head by means of four screws, as shown in the drawing.

24 Installing the alignment tool

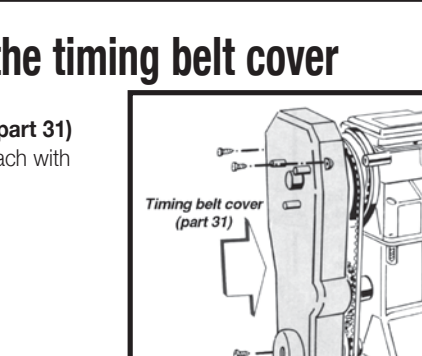
The alignment tool is used to lock the position of the timing wheel while the timing belt is being installed. Carefully identify the reference marks and holes that let you correctly position the alignment tool (part 29) between the timing wheel and the timing gear.

**25 Installing the timing belt and timing belt pulley**

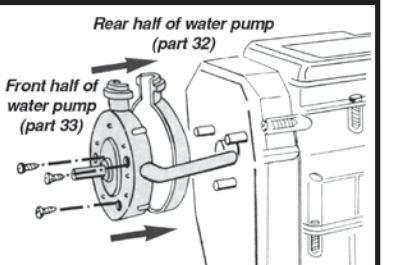
Place the timing belt (green color) over the timing gear and timing wheel. Mount the belt pulley (part 30) on the upper post sticking out from the cylinder block (the smooth side of the timing belt rests against the pulley). Once these two steps have been performed, remove the alignment tool; it must not remain attached to the engine.

**26 Installing the timing belt cover**

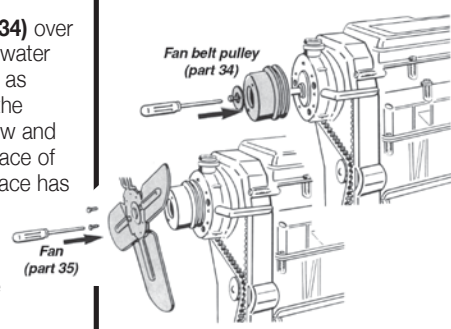
Mount the timing belt cover (part 31) as shown in the drawing. Attach with four screws.

**27 Installing the water pump**

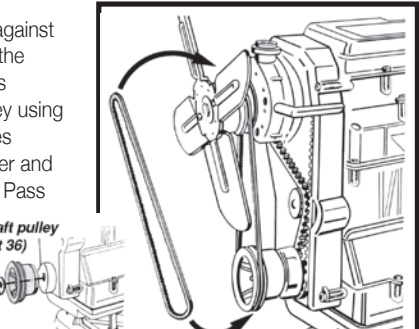
Press the rear half of the water pump (part 32) onto the timing belt cover; make sure it is oriented as shown in the drawing. Place the front half of the water pump (part 33) against the rear half. Join the two halves by means of three screws.

**28 Installing the fan belt pulley and fan**

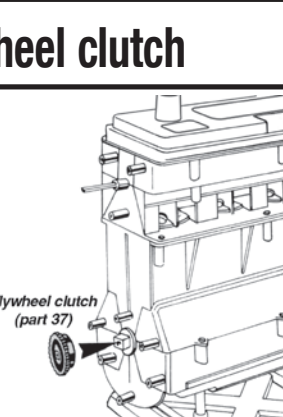
Place the fan belt pulley (part 34) over the shaft sticking out from the water pump. Make sure it is oriented as shown in the drawing. Attach the pulley to the shaft using a screw and a washer. Identify the outside face of the fan (part 35) (the outside face has ribs - see drawing). Hold the fan against the fan belt pulley with the outside of the fan facing towards you. Attach the fan with two screws.

**29 Installing the crankshaft pulley and fan belt**

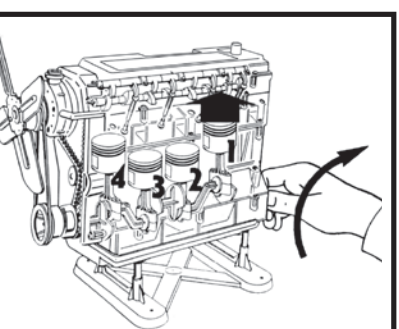
Place the crankshaft pulley (part 36) against the circular shoulder at the bottom of the timing belt cover. Position the pulley as shown in the drawing. Attach the pulley using a screw and washer. Thread the fan belt (black color) over the top of the fan blades and install it on the fan belt and crankshaft pulleys.

**30 Installing the flywheel clutch**

Mount the flywheel clutch (part 37) on the opposite end of the crankshaft. Next, we'll check the entire engine by rotating the crankshaft by hand. Notice carefully what happens.

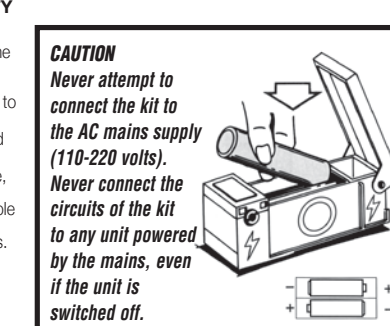
**31 Positioning the pistons and camshaft**

Preliminary adjustment: Gently rotate the crankshaft by hand until piston Number 1 is at the top of its vertical travel. (This position is called "dead center"). The flat portion of the half-round camshaft should be horizontal, with the flat portion facing upwards. Once you have verified that the piston and the camshaft are in the correct position, continue with the next step.

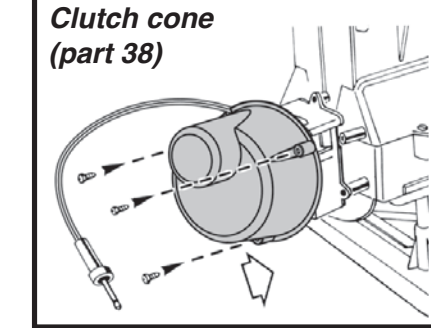
**32 Installing the batteries**

In the Motor Works kit, electric power is provided by two 1.5 volt batteries (Type AA). Take a look at the battery box, inside the box you will see the outline of two batteries showing the polarity (+ and -) of each battery. Install the batteries as follows:
• Push the + end of the battery against the spring.
• Press the - end of the battery downwards until it is firmly seated in its compartment.
Any type of 1.5 volt battery will work: AA, SPT, LPR, MN 1500 (alkaline), etc.

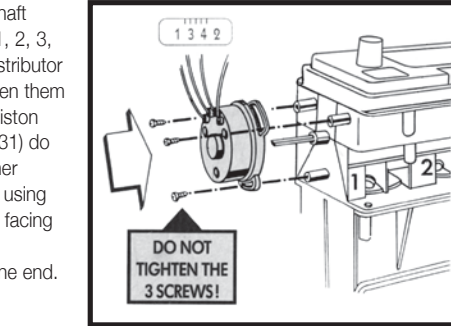
BATTERY SAFETY INFORMATION:
• Only batteries of the same or equivalent type as recommended are to be used.
• Do not mix old and new batteries.
• Do not mix alkaline, standard carbon-zinc or rechargeable (NiCd) batteries.
• Do not attempt to "jump" batteries.
• Dispose of used batteries safely and correctly.

**37 Attaching the clutch cone**

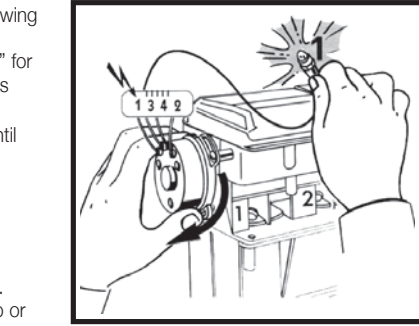
Feed the wire from the drive module through the opening in the clutch cone (part 38). Line up the three holes in the clutch cone with the three studs on the engine. Attach the clutch cone with three screws.

**33 Installing the distributor assembly**

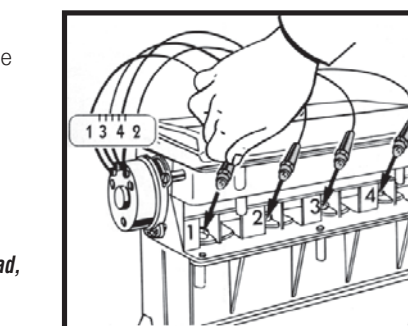
Mount the distributor on the camshaft such that the identification marks 1, 2, 3, and 4 are at the top. Attach the distributor cover with three screws, but do not tighten them yet. Mind that the position of the piston and camshaft (established in step 31) do not shift. The distributor has an inner socket that spans. Turn this socket using the screwdriver until the flat side is facing up. Two of the wires from the distributor have a phone jack on one end. Plug this jack into the socket on the battery box.

**34 Adjusting the ignition**

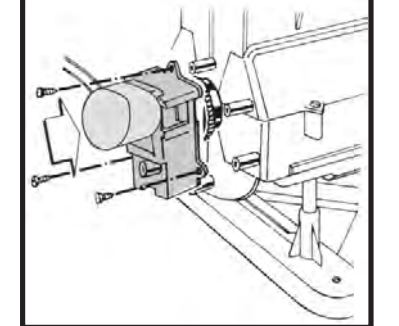
Identify lamp Number 1 by following the blue wire from the "1" mark on the distributor. (Lamp #1 is the "spark plug" for cylinder #1.) Adjust the ignition system as follows:
• Gently rotate the distributor housing until lamp #1 lights.
• With lamp #1 lit, tighten the three distributor screws.
• Remove the distributor plug from the battery box socket.
The ignition system is now fully adjusted. You can now continue with the next step or repeat this step; take all the time you need.

**35 Installing the spark plugs**

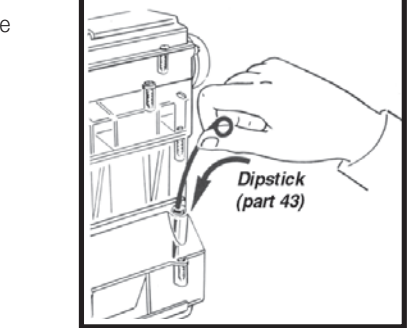
Insert the four spark plugs in their respective receptacle in the lower cylinder head.

**36 Attaching the drive module**

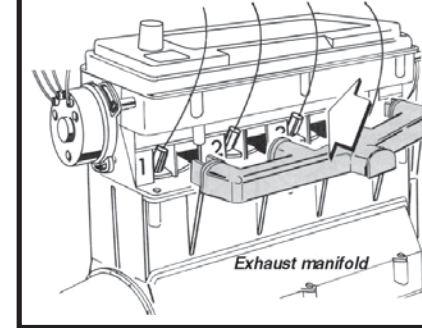
Position the drive module by meshing its gear teeth with those on the flywheel clutch. Attach the module to the engine with three screws.

**39 Installing the dipstick**

Insert the dipstick (part 43) in the cylinder block. The hole for the dipstick is also on the side opposite the spark plug.

**40 Installing the exhaust manifold**

On the spark plug side of the engine, install the exhaust manifold (part 42) in the lower cylinder head.

**41 Operating the engine**

The long-awaited moment has arrived! You will now have the opportunity to run your engine for the first time. First, plug the cables from the distributor and the drive module into the battery box. When the latter cable is connected, the engine should start to turn. Note the direction in which the fan blades turn. Theoretically, the fan blades of all automotive engines turn in the same direction. Did you know this? Removing the drive module plug from the battery box stops the engine. By successively connecting and disconnecting this plug, you can start and stop the engine just as if you were turning it on and off with a switch. Note, in each instance, the position of the pistons and the sequence in which the spark plugs are "firing". This will help you understand the operating principle for a 4-stroke internal combustion engine.

