The Smithsonian Institution is a museum, education and research complex of 17 museums and galleries, and the National Zoological Park. Fifteen museums and galleries are located in Washington, D.C., two are in New York City, and the National Zoo is in Washington. Ten of the museums and galleries are situated on the National Mall between the U.S. Capitol and Washington Monument. One of the world’s leading scientific research centers, the Institution has facilities in eight states and the Republic of Panama. Research projects in the arts, history, and science are carried out by the Smithsonian all over the world. The new National Museum of the American Indian is scheduled to open on the National Mall in 2002. The centerpiece of the museum is the priceless collection of Native American artifacts transferred to the Smithsonian from the Museum of the American Indian, Heye Foundation (New York). The New York exhibition facility - the Heye Center of the National Museum of the American Indian opened October 30, 1994 in lower Manhattan. Another new museum, the National Postal Museum, is located near Union Station on Capitol Hill. Devoted to the history of the U.S. mail service, the museum houses the world’s largest and most comprehensive collection of its kind, with more than 16 million stamps, covers, and artifacts.

HISTORY
James Smithson (1765-1829), a British scientist, drew up his will in 1826 naming his nephew, Henry James Hungerford, as beneficiary. Smithson stipulated that should the nephew die without heirs (as he did in 1835), the estate would go to the United States to found “at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge...”

On July 1, 1836, Congress accepted the legacy bequeathed to the nation by James Smithson, and pledged the faith of the United States to the charitable trust. In 1838, following approval of the bequest by the British courts, the United States received Smithson’s estate - bags of gold sovereigns - then the equivalent of $515,169. Eighty years later, on August 10, 1846, an Act of Congress signed by President James K. Polk, established the Smithsonian Institution in its present form and provided for the administration of the trust, independent of the government itself, by a Board of Regents and Secretary of the Smithsonian.

SMITHSONIAN MUSEUMS, GALLERIES AND ZOOS

Anacostia Museum
Arthur M. Sackler Gallery
Arts and Industries Building
Cooper-Hewitt, National Design Museum
Freer Gallery of Art
Hirshhorn Museum and Sculpture Garden
National Air and Space Museum
National Museum of African Art
National Museum of African History
National Museum of the American Indian
National Museum of Natural History
National Portrait Gallery
National Postal Museum
National Zoological Park
Smithsonian American Art Museum
Smithsonian Institution Building (“Castle”)

DEAR CUSTOMER,
If we made an error and left something out of this set, or if something is damaged, we are sorry and wish to correct our error. Please do not return the set to the store where you purchased it, or to the Smithsonian, as they do not have replacement parts. Instead, write us a letter giving us:

1. Date of Purchase
2. Where Purchased
3. Model Number
4. Name of Set
5. Brief Description of Problem
6. Sales Slip

We will do our best to satisfy you. Quality Control Department, Natural Science Industries, Ltd. 910 Orlando Avenue, West Hempstead, NY 11552-3942. (888) 425-9113.

SMITHSONIAN MOTOR-WORKS™

BATTERY SAFETY 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.
- Empty 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.
- This toy must be used with the recommended transformer. The transformer is not a toy.
- Toys liable to be cleaned with liquid are to be disconnected from the transformer before cleaning.

Item #90804
Ages 8 and up

THE SMITHSONIAN INSTITUTION FACT SHEET

SMITHSONIAN INSTITUTION
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The engine you are going to build is a greatly simplified version of a real engine. This will make it easier for you to understand the operation of a four-stroke, internal combustion engine. Consequently, the following components are not included: oil filter, liquid cooling system, air filter, connecting rod bearings, rings, oil pump, fuel pump, alternator and a starter.

On the other hand, the following components, which are included so you can identify their location on the engine, are not intended to function: water pump, carburetor, dipstick (without oil), flywheel clutch. A drive module, powered by a small electric motor, replaces the starter.

What is this kit all about?
First, you'll identify and assemble the various parts, module by module, with the help of the explanations provided in this manual. Once you've done this, you'll have the pleasure of seeing the four-stroke, internal combustion engine you've just built in operation. You'll also see the spark plugs “fire” in the correct sequence - just like a real engine!

Most engines used in today's cars and trucks are 4-stroke cycle engines, just like this one.

The explanations in this manual will help you understand how the engine in your parents' car operates.
Later on you'll be able to expand your knowledge and become a “whiz” on internal combustion engines.

Most of the energy produced by the gas consumed in an internal combustion engine is converted into power to do work. But a significant amount of energy in the form of heat is also produced. Temperatures inside modern automobile engines can easily reach 1700 degrees Celsius and engines must be cooled, even in the winter. Four-cycle engines usually use two methods to remove this heat.

Convection
As the Motorworks model shows, a fan is often attached to the front of the engine and blows air over it to help keep it cool. Some engines, like those on lawnmowers also have metal fins to increase the surface area of the engine and make it easier for heat to escape.

Radiators
For large and powerful engines like those in cars and trucks, most of the cooling is done by circulating fluids that pass through channels in the engine. This fluid is kept moving by a “water” pump which is powered by the engine. The coolant absorbs heat as it passes through the engine and then releases the heat to the air as it passes through the Radiator. A radiator is just a series of narrow tubes with fins that allow air to flow over them and remove the heat. Radiators are almost always located at the front of the vehicle to make it easy for the air to pass over them. Many modern cars have an electric fan that continues to cool the engine after it is turned off. Sometimes you can hear these fans running as you walk away from the car on a hot summer day.

Lubrication
The moving parts in an engine must be precisely made to work properly. To reduce the friction between these parts as they move, it is necessary to lubricate them with oil. Car and truck motors use several quarts of oil to keep everything lubricated and this is stored in the Oil Pan at the bottom of the engine. Every engine has a Dip Stick that reaches down into this oil and lets you make sure that the engine has enough.

An Oil Pump, mechanically connected to the engine, circulates oil throughout engine. The cylinder walls are lubricated by oil that is splashed by the moving crankshaft. As it circulates, the oil also carries away dirt and chemicals left over from combustion. These are removed by the Oil Filter.

Further Reading
To learn more about internal combustion engines and how they work, check with the public library or search the World Wide Web for terms like "internal combustion."
**FUEL AND AIR - THE EXPLOSIVE MIXTURE**

As we said earlier, the power in a gasoline engine comes from carefully burning a mixture of gasoline and air. The part of the Motorworks engine that mixes gas and air is called a Carburetor.

A carburetor adds gas to the air as it flows into the engine. It takes a surprisingly small amount of gasoline to provide the push needed in each power stroke. On average, it only takes about 10 milligrams per stroke, but the mixture is very sensitive. If too much gas is put in the cylinder, the engine “runs rich.” Not only will the engine waste fuel, but it will produce smoky exhaust, run poorly (stall easily and hesitate on acceleration) and it may not even run at all. If not enough gas is put in the cylinder, the engine “runs lean.” A lean mixture can keep the engine from starting and can even damage it.

To provide a more precise mixture and to reduce exhaust pollution, the carburetor has now been replaced on automobiles by a system called fuel injection. Since 1991 every new car sold in the United States has used fuel injection, but smaller engines like those on lawn mowers and chainsaws continue to use carburetors because they are simple and inexpensive.

Several other systems have been developed to control the mixture of fuel and air that goes into an engine. Superchargers and Turbochargers both use a pressurized mixture of air and gas to increase the power that can be produced by a gasoline engine.

**STARTING THE CAR**

The power that starts a car comes from the battery. Once it is running, an electric generator (called an Alternator) that is connected to the motor by a pulley produces all the electricity the engine needs to run. Indeed, although it is not recommended, a car’s battery can actually be removed once it is running.

When you turn the key on an automobile to “Start”, power from the battery goes to the Starter Motor, which turns the crankshaft and moves the pistons. At the same time, electricity goes to the Ignition Coil, where the voltage is increased to 15,000 volts. This high voltage electricity, which is needed to produce a strong spark, is sent to the spark plugs to ignite the gas/air mixture. As soon as the gas in the cylinders begins to explode, the engine can run on its own and the key can be turned back to the “On” position.

The first gasoline engines had no battery. To start them, the crankshaft had to be turned mechanically and a device called a “magneto” would provide the electricity to fire the spark plugs. This is why early cars like the Ford Model “T” had a crank in the front that had to be turned to start them. Later this was replaced by batteries and mechanical ignitions. Today most cars and trucks have what is called an Electronic Ignition system, which is much safer and easier to use.
BEFORE ASSEMBLING YOUR ENGINE WE SUGGEST:

1. First, thoroughly identify the various components by trying to learn the name of each part. In so doing, make good use of the drawings included in this manual.

2. Remove the parts from the plastic molding as you need them, and strictly follow the order of assembly indicated on the following pages. Otherwise, you will run into problems because you won’t know which number goes with which part (there are no numbers on the parts themselves). In any case, the drawings on the following pages are intended to help you. Refer to them any time you have a question on the identity of a part.

3. After separation from the plastic mold, small burrs may remain on some parts. Remove these burrs by means of a knife or other cutting implement. Otherwise, they could hinder proper operation of the engine. (Have an adult help with this step.)

4. If several screws are to be mounted on the same part, first place all the screws in position and tighten them lightly by hand.

5. Think carefully about the position of each part before attaching it permanently (be aware of the possibility of installing it upside-down, backwards, etc.). In this regard, note the reference numbers indicated on the assembly drawings shown on the following pages. Otherwise, you may have to start over.

6. You should lightly oil all of the bearings so the various parts of your Motor Works Engine will operate smoothly. Use vegetable oil; there should be some in your kitchen. (Note: A “bearing” is any part of a machine that supports a rotating shaft.)

YOUR GOAL should be to assemble your engine properly on the first try, and to have it operate right away. Being able to do this will give you enormous satisfaction. If you follow these recommendations for assembling your engine, you will accomplish this goal.
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.

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.

LIST OF PARTS

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 washers, 9.5 mm ø</td>
<td></td>
</tr>
<tr>
<td>1 shaft, 3 mm ø, 156 mm long</td>
<td></td>
</tr>
<tr>
<td>1 shaft, 3 mm ø, 206 mm long</td>
<td></td>
</tr>
<tr>
<td>(half round)</td>
<td></td>
</tr>
<tr>
<td>4 exhaust valves</td>
<td>13</td>
</tr>
<tr>
<td>4 intake valves</td>
<td>14</td>
</tr>
<tr>
<td>8 valve stems</td>
<td>12</td>
</tr>
<tr>
<td>4 piston pins</td>
<td>1</td>
</tr>
<tr>
<td>8 pistons</td>
<td>3</td>
</tr>
<tr>
<td>4 connecting rod keepers</td>
<td></td>
</tr>
<tr>
<td>(big end)</td>
<td>5</td>
</tr>
<tr>
<td>4 connecting rods</td>
<td>2</td>
</tr>
<tr>
<td>8 timings cams</td>
<td>A-H</td>
</tr>
<tr>
<td>8 rocker arms</td>
<td>24</td>
</tr>
<tr>
<td>1 crankshaft</td>
<td>4</td>
</tr>
<tr>
<td>1 crankshaft pulley</td>
<td>36</td>
</tr>
<tr>
<td>1 fan pulley</td>
<td>34</td>
</tr>
<tr>
<td>1 fan</td>
<td>35</td>
</tr>
<tr>
<td>1 engine mounting stand</td>
<td>8</td>
</tr>
<tr>
<td>5 bearings</td>
<td>25</td>
</tr>
<tr>
<td>1 clutch housing</td>
<td>38</td>
</tr>
<tr>
<td>1 oil-pan</td>
<td>6</td>
</tr>
<tr>
<td>1 lower crankcase</td>
<td>7</td>
</tr>
<tr>
<td>1 cylinder block</td>
<td>9</td>
</tr>
<tr>
<td>1 rocker arm cover</td>
<td>26</td>
</tr>
<tr>
<td>1 upper cylinder head</td>
<td>23</td>
</tr>
<tr>
<td>1 timing belt (green)</td>
<td></td>
</tr>
<tr>
<td>1 timing wheel</td>
<td></td>
</tr>
<tr>
<td>1 timing gear</td>
<td></td>
</tr>
<tr>
<td>1 belt tensioning pulley</td>
<td></td>
</tr>
<tr>
<td>1 lower cylinder head</td>
<td></td>
</tr>
<tr>
<td>1 lower cylinder block</td>
<td></td>
</tr>
<tr>
<td>1 dipstick</td>
<td>43</td>
</tr>
<tr>
<td>1 positioning jig</td>
<td>29</td>
</tr>
<tr>
<td>1 timing belt cover</td>
<td>31</td>
</tr>
<tr>
<td>1 intake manifold</td>
<td>40</td>
</tr>
<tr>
<td>1 exhaust manifold</td>
<td>42</td>
</tr>
<tr>
<td>1 aluminum carburetor</td>
<td></td>
</tr>
<tr>
<td>cover</td>
<td>41</td>
</tr>
<tr>
<td>1 carburetor bowl</td>
<td>39</td>
</tr>
<tr>
<td>1 front half of water pump</td>
<td>33</td>
</tr>
<tr>
<td>1 rear half of water pump</td>
<td>32</td>
</tr>
<tr>
<td>1 aluminum flywheel clutch</td>
<td>37</td>
</tr>
<tr>
<td>1 fan belt</td>
<td></td>
</tr>
<tr>
<td>1 head gasket</td>
<td>10</td>
</tr>
<tr>
<td>8 valve springs</td>
<td></td>
</tr>
<tr>
<td>1 distributor assembly</td>
<td></td>
</tr>
<tr>
<td>1 drive module</td>
<td></td>
</tr>
<tr>
<td>1 battery box</td>
<td></td>
</tr>
<tr>
<td>67 screws</td>
<td></td>
</tr>
<tr>
<td>screwdriver</td>
<td></td>
</tr>
</tbody>
</table>
How a Gas Engine Works

Internal Combustion

The Motorworks 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 Motorworks 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
CONGRATULATIONS!
You have successfully built your own model engine. Please observe your engine. It should look like the drawing.
Installing the Exhaust Manifold

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

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. You'll find more about this principle on the following pages.
38 MOUNTING THE CARBURETOR AND THE INTAKE MANIFOLD

Place the carburetor bowl (part 39) on the intake manifold (part 40). Attach the carburetor cover (part 41) by means of a screw into the intake manifold/carburetor bowl assembly. Now install the intake manifold/carburetor assembly you have just finished on the engine. Note that it goes on the side opposite the spark plugs.

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 plugs.
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.

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.
**34 ADJUSTING THE IGNITION**

Carefully identify lamp Number 1 by following the red wire from the "1" mark on the distributor. (Lamp Nr. 1 is the "spark plug" for cylinder Nr. 1)

Adjust the ignition system as follows:
- Gently rotate the distributor housing until lamp Nr. 1 lights.
- With lamp Nr. 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 receptacles in the lower cylinder head.

**NOTE!**

Pay careful attention to the order in which the four spark plugs are installed. Trace each red wire to ensure that plug Nr. 1 goes to the "1" hole in the lower cylinder head, Nr. 2 goes to the "2" hole, etc.
**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, SP7, LR6, MN 1500 (alkaline), etc.

**CAUTION**

Never attempt to connect the kit to any AC supply (110-220 volts). Never connect the circuits of the kit to any unit powered by the main power supply, even if the unit is switched off.

**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 (nickel-cadmium) batteries.
- Do not attempt to burn batteries.
- Dispose of batteries safely and correctly.

**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 with three screws, but do not tighten them yet. Make sure that the position of the piston and camshaft (established in step 31) do not shift. The distributor has an inner socket that spins. 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.
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.

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ASSEMBLING YOUR MOTOR WORKS ENGINE

ASSEMBLING THE PISTONS

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

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.

INSTALLING THE CRANKSHAFT PULLEY AND FAN BELT

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.

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.

The screw passes through the hole in the timing belt cover and screws into the end of the crankshaft. Pass the fan belt (black color) over the top of the fan blades and install it on the fan belt and crankshaft pulley.
26 INSTALLING THE TIMING BELT COVER

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

![Timing belt cover](part 31)

27 INSTALLING THE WATER PUMP

Press the rear half of the water pump (part 32) onto the three studs on 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.

![Rear half of water pump](part 32)

![Front half of water pump](part 33)

3 MOUNTING THE PISTONS ON THE CRANKSHAFT

NOTE!

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.

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).

![Crankshaft](part 4)

![Connecting rod 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.

Rotate the crankshaft. The pistons should dangle freely without binding on the crankshaft.
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).

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. Install the alignment tool.

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.
**22 Mounting the Timing Gear on the Crankshaft**

Put the timing gear (part 27) on the splined end of the crankshaft.

**NOTE!**

There is only one correct position for this part. Note the reference marks on the drawing. Make sure the reference marks on the parts match those shown in the drawing. This gear must slide freely onto the crankshaft. If you have to force it, then the positioning is incorrect.

**23 Mounting the Timing Wheel on the Camshaft**

Press the timing wheel (part 28) onto the camshaft while pushing against the opposite end of the camshaft with your finger to prevent the camshaft from moving. If the camshaft moves, you will have to realign the cams.

**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 in 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.)
Fasten the two units together with six screws. Check the overall assembly, at this point, for proper operation: Rotate the crankshaft by hand. The cylinders should move freely up and down inside their respective cylinders.

**10 Installing the Springs on the Valve Stems**

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

**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.

**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.
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).

**Note:** Strictly follow the mounting sequence given below because each cam has a different orientation angle. Slide the cams onto the camshaft in the following order: 1st=A; 2nd=B; 3rd=C; 4th=D; 5th=E; 6th=F; 7th=G; 8th=H.

INSTALLING THE CAMSHAFT ON THE LOWER CYLINDER HEAD

First, make sure the splined (grooved) end of the crankshaft 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.

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 holds 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.

In the same manner, install the other four valve stems (and springs) into 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
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). As a check: the first and the last rocker arms should not be oriented the same way.

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 lower 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.