## Section 1 Topics

### Internal Combustion Engine Operation

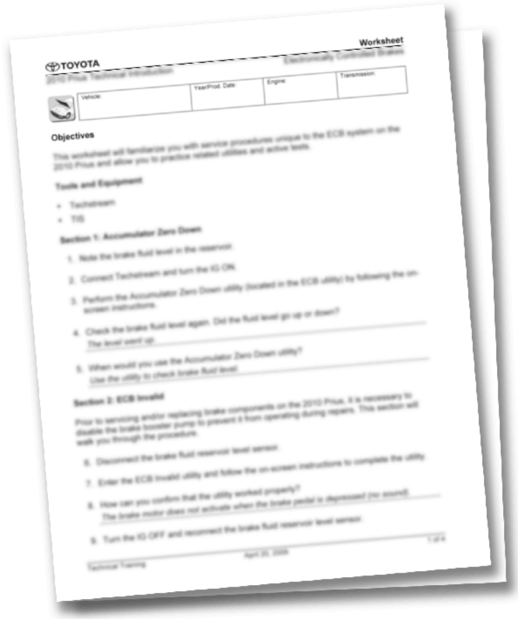
- Primary Engine Components
- 4-Stroke Cycle
- Intake
- Compression
- Combustion
- Exhaust
- Engine/Block Designs
- Engine Position and Cylinder Identification
- Engine Serial Number Location
- Engine Decoder

- Internal Combustion Engine Worksheet

# Worksheet

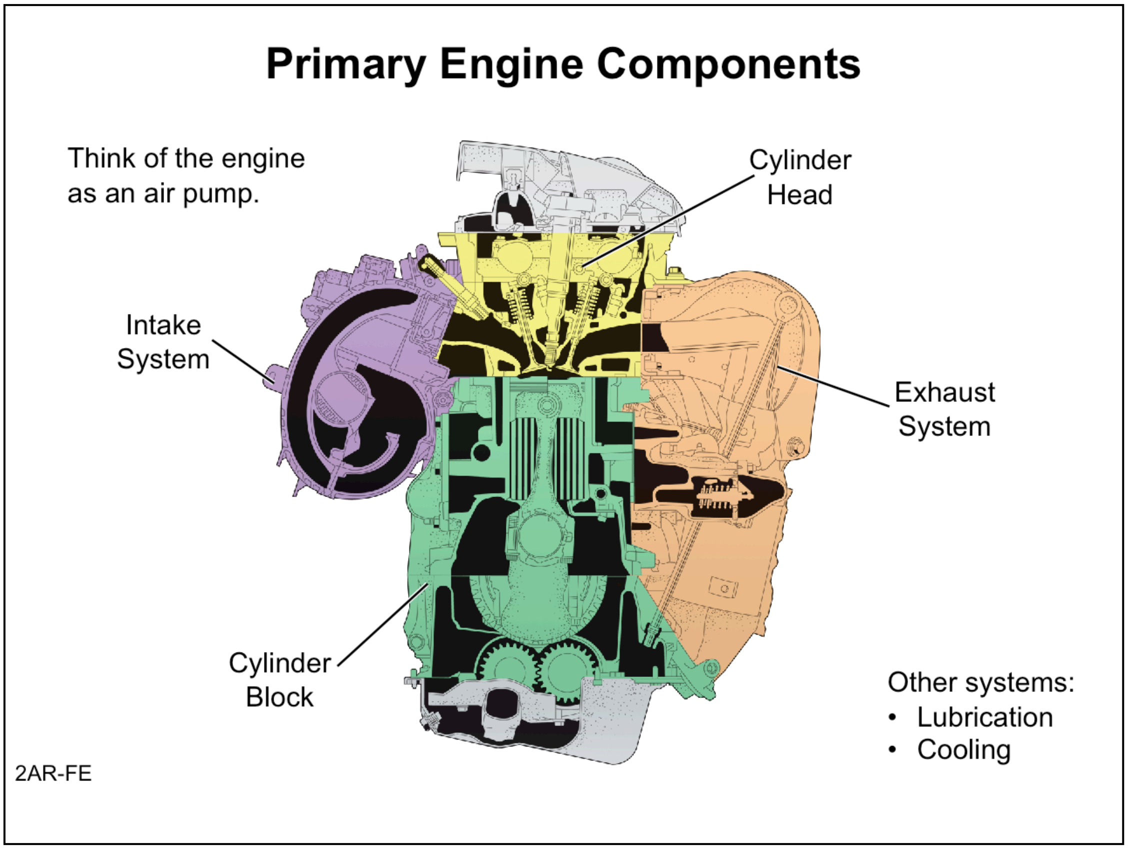
### Internal Combustion Engine

This worksheet is to evaluate what you already know about internal combustion engine operation and components.


TOYOTA
Worksheet
Objectives

*Use this space to write any questions you may have for your instructor.*

**NOTES**:




## Primary Engine Components

The internal combustion engine is made up of four major systems/components.

**Intake –** The intake system channels air to the intake side of the cylinder head.

**Exhaust –** The exhaust system channels the combusted air-fuel mixture away from the combustion chamber and vehicle.

**Cylinder Head –** The cylinder head seals the top of the combustion chamber and controls the incoming air-fuel mixture and exiting exhaust gases.

**Cylinder Block –** The cylinder block houses the piston and crankshaft assembly. These two components convert linear (up and down) motion into rotational motion.

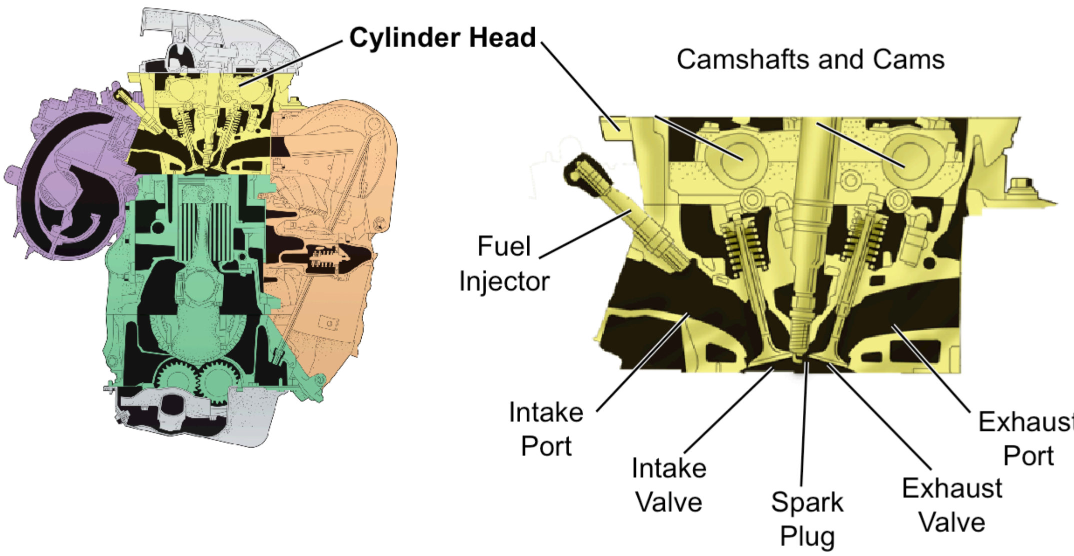
### Other Engine Systems

Other primary engine systems include:

**Lubrication System –** The lubrication system uses a pump to deliver oil to all necessary components within the engine.

**Cooling System –** As a result of burning fuel, **i**nternal combustion engines produce heat. The cooling system keeps the engine's internal temperature regulated.

## Cylinder Head Basic Components

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### Cylinder Head Components

The cylinder head is bolted to the top of the cylinder block and provides a path for the air-fuel mixture to enter the cylinder (intake port), and a path for spent gases to exit the cylinder (exhaust port). It also controls the timing of the opening and closing of the ports, and houses the fuel injectors and spark plugs.

Cylinder head components and their functions are:

**Intake Port** – The intake port is the passageway through which fuel and air enter the cylinder.

**Exhaust Port** – The exhaust port is the passageway through which exhaust gases exit the cylinder.

**Intake Valve** – When closed, the intake valve seals the passageway between the intake port and the cylinder. When opened by the rotating cam, air and fuel are able to enter the cylinder.

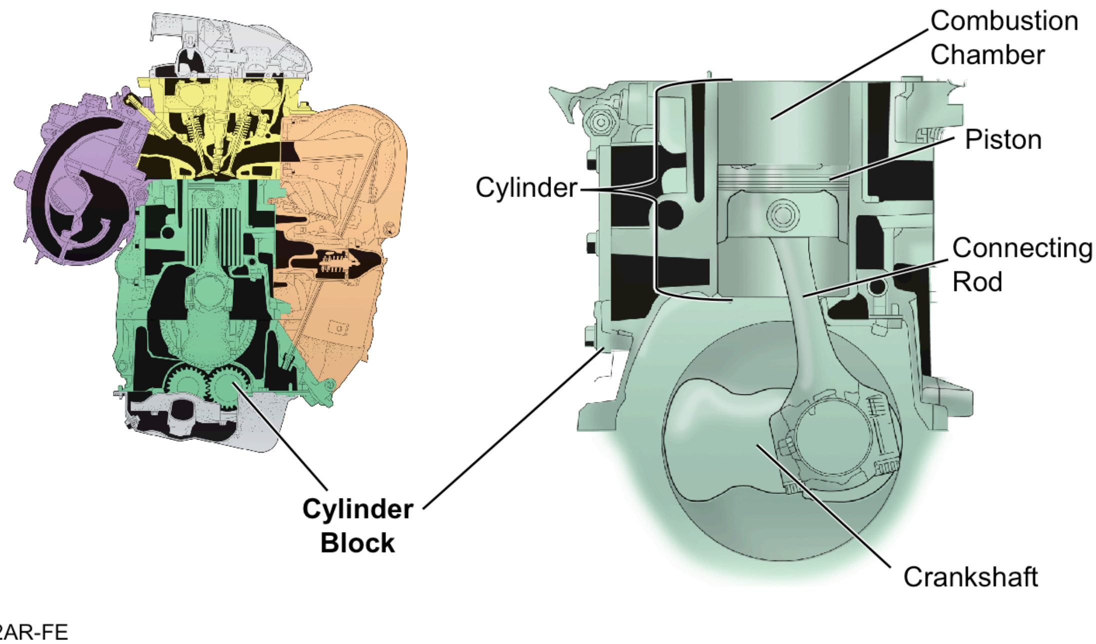
**Exhaust Valve** – When closed, the exhaust valve seals the passageway between the exhaust port and the cylinder. When opened by the rotating cam, exhaust gasses are able to exit the cylinder.

**Fuel Injector** – Just prior to the intake stroke, this high pressure valve opens and sprays fuel into the intake port.

**Spark Plug** – At the appropriate moment, the spark plug ignites the air-fuel mixture and the resulting expansion of hot gases powers the engine.

**Camshafts and Cams** – The rotating cams on the camshafts control the timing of intake and exhaust valve opening and closing. In the dual overhead cam (DOHC) engine design, one camshaft controls the intake valves and the other camshaft controls the exhaust valves.

## Cylinder Block Basic Components




### Cylinder Block Components

The cylinder block houses the cylinders, and the piston and crankshaft assemblies.

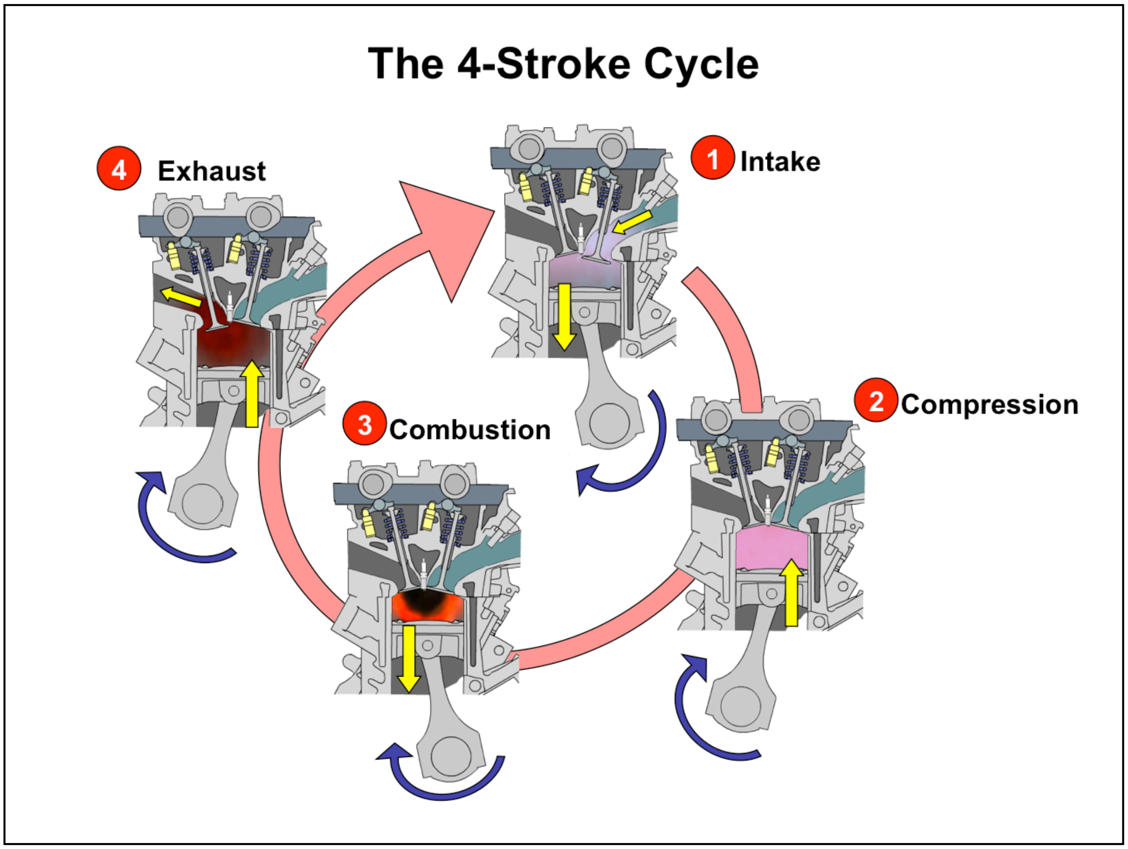
**Cylinder –** The cylinder is a relatively large hole bored into the block providing a hollow chamber in which the piston operates.

**Piston –** The piston and piston rings fit snugly inside the cylinder, effectively creating a seal. The piston is able to move up and down inside the cylinder, allowing the air-fuel mixture to enter the cylinder as the piston moves downward, and allowing exhaust gases to exit as it moves upward.

**Combustion Chamber –** The combustion chamber refers to the sealed portion of the cylinder above the piston where combustion takes place.

**Connecting Rod –** The connecting rod attaches the piston to the crankshaft.

**Crankshaft –** The crankshaft converts the up-and-down motion of the piston into rotary motion. This is accomplished by attaching the connecting rod off-center to the crankshaft.



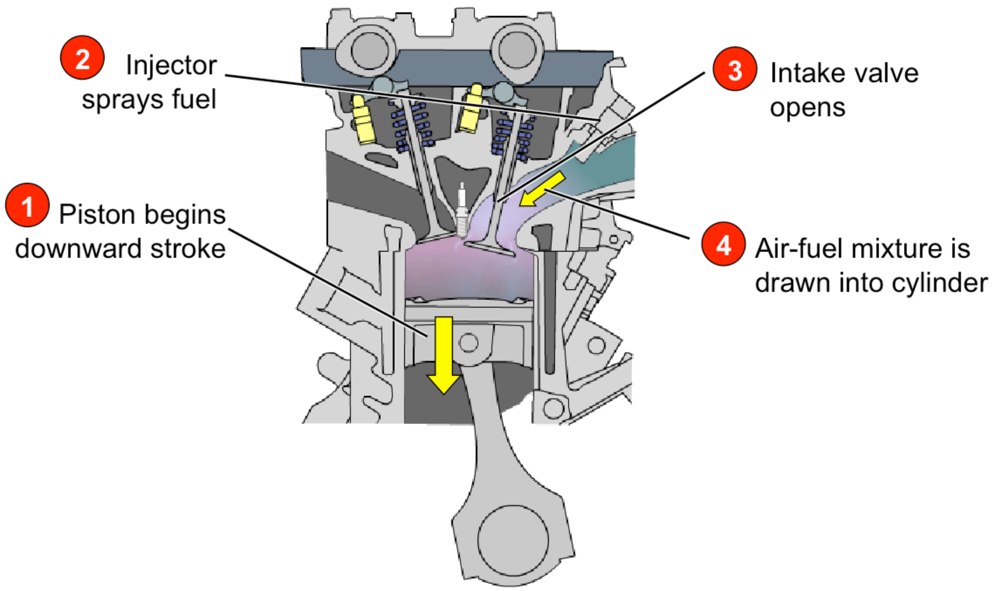

**The 4-Stroke Cycle**

Nikolaus Otto invented the basic 4-stroke internal combustion engine in 1867. Although modern engineering and electronics have completely revolutionized engine technology, today's engines still operate on the principals of Otto's 4-stroke cycle.

The four strokes are:

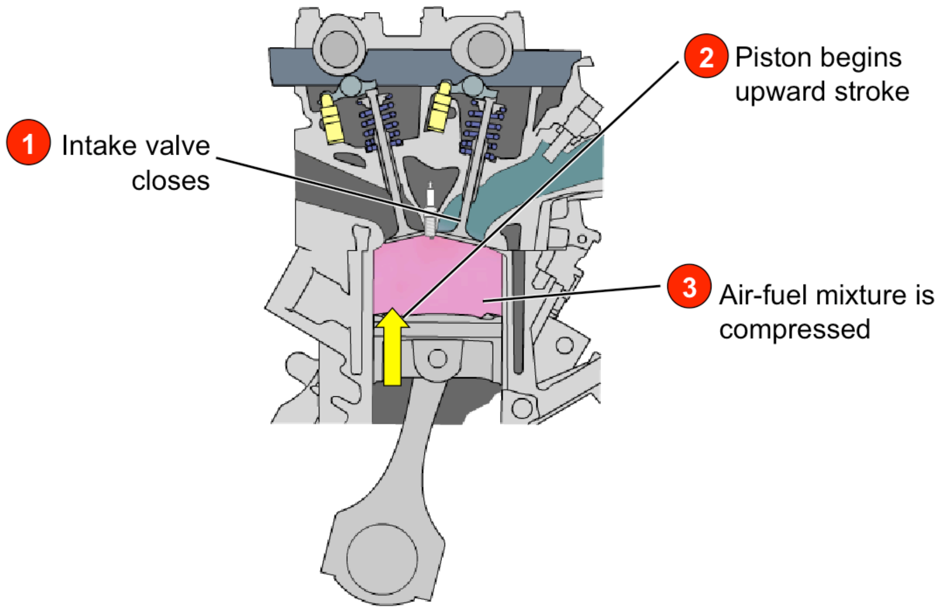
- Intake Stroke
- Compression Stroke
- Combustion (Power) Stroke
- Exhaust Stroke

## Intake Stroke

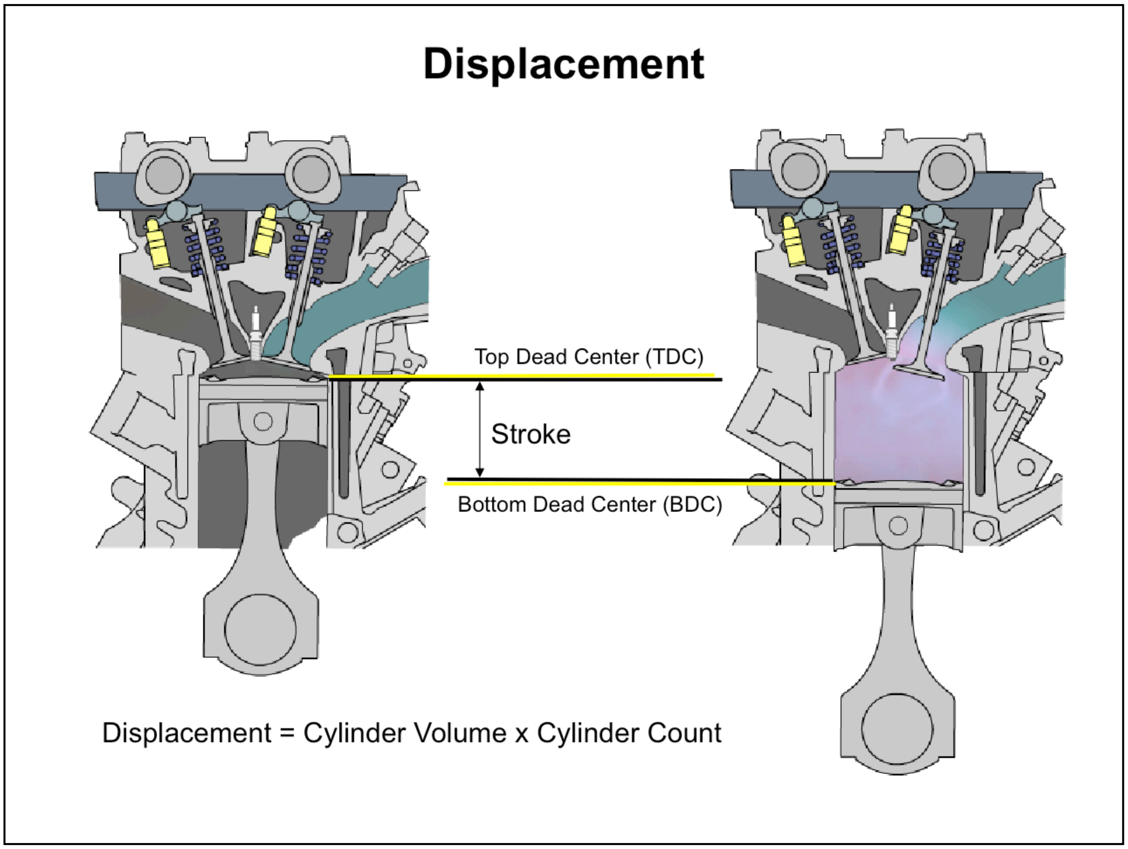



**Intake Stroke** Just before the camshaft opens the intake valve, the injector sprays fuel into the intake port. As the camshaft opens the intake valve, the piston is traveling downward creating a negative pressure in the cylinder. Atmospheric pressure pushes the air-fuel mixture into the cylinder to fill the vacuum.

## Compression Stroke




**Compression Stroke** At the beginning of the compressions stroke, the intake valve closes and the piston begins traveling upward compressing the air and fuel mixture. Compressing the mixture raises the temperature of the gas mixture within the cylinder and increases its potential energy. The rising temperature pre-heats the mixture and helps further vaporize the fuel.

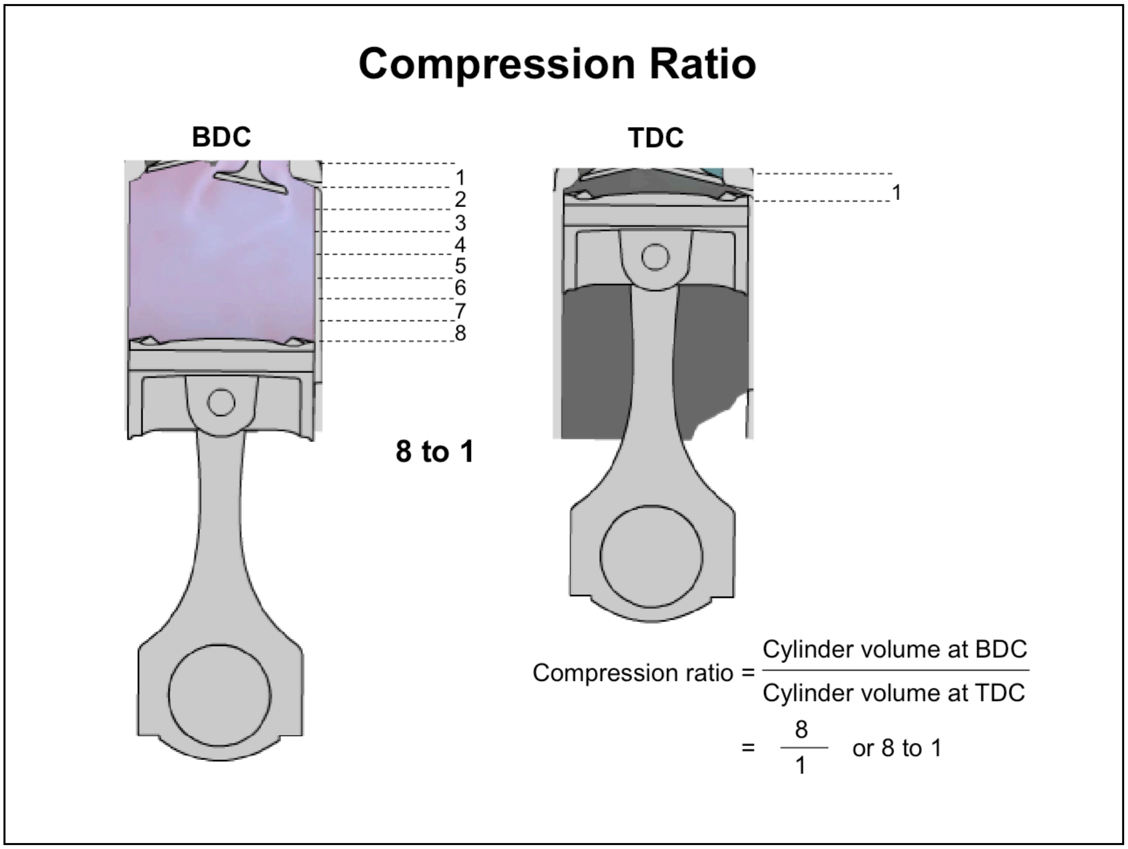



*Displacement*

The piston's stroke is the distance between the farthest points on the piston's path of travel.

- Top dead center (TDC) is the highest point of the piston's stroke.
- Bottom dead center (BDC) is the lowest point of the piston's stroke.

To calculate the engine's **displacement** (such as 5.7 liters), determine the cylinder volume when the piston is at BDC and multiply it by the number of cylinders.



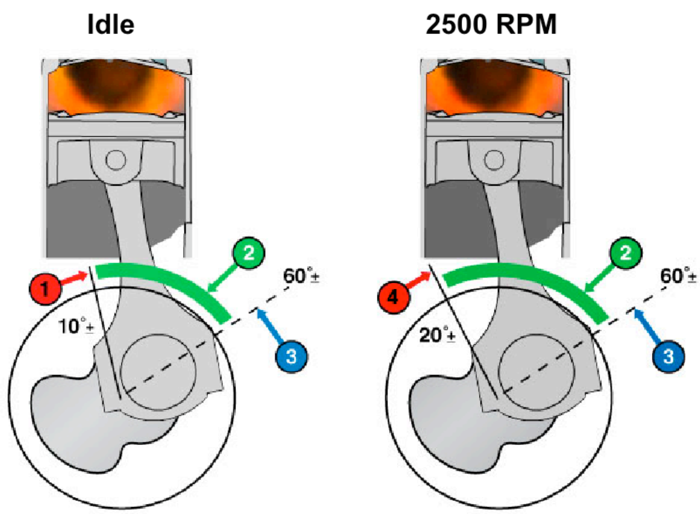

*Compression Ratio* At BDC, the combustion chamber is at its maximum volume. At TDC, the chamber reaches its minimum volume. The ratio of these two volumes is the engine's compression ratio.

The higher the compression ratio, the more energy can be extracted from the combustion process.

## Ignition Timing

The spark plug fires just before the piston reaches the top of the compression stroke (TDC).

1. At idle, ignition occurs when the connecting rod is approximately 10º before TDC.
2. It takes 3 milliseconds to reach maximum combustion pressure.
3. Maximum combustion pressure reached when connecting rod is approximately 60º after TDC.
4. At 2500 rpm, ignition occurs when the connecting rod is approximately 20º before TDC.



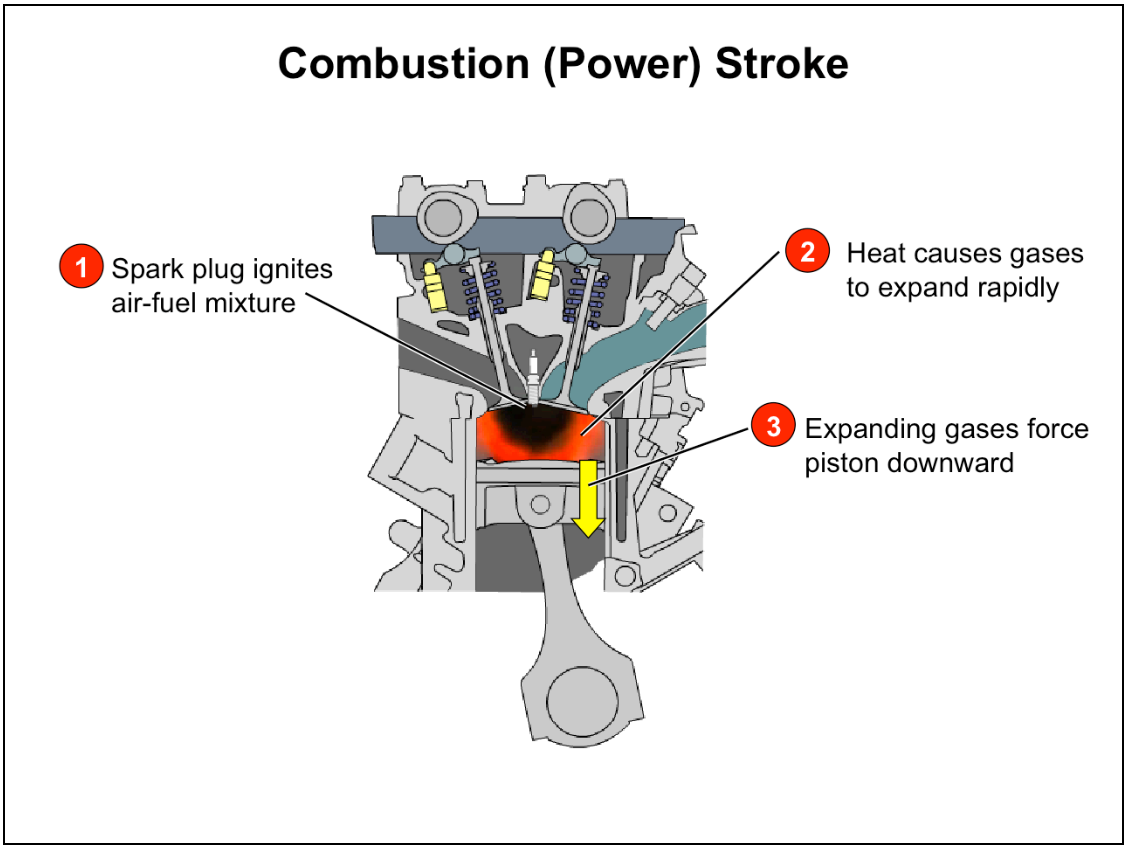

*Ignition Timing*

The spark plug ignites the fuel just before the piston reaches Top Dead Center (TDC) so that when gas expansion occurs, the piston is beginning its downward stroke. To obtain optimum power transfer from combustion, maximum combustion pressure should occur when the connecting rod reaches approximately 60º after TDC.

As RPM increases, keeping maximum combustion pressure occurring at 60º after TDC can require ignition to occur sooner. This is referred to as timing advance (or ignition advance). Timing advance enables the engine to continuously operate at maximum power

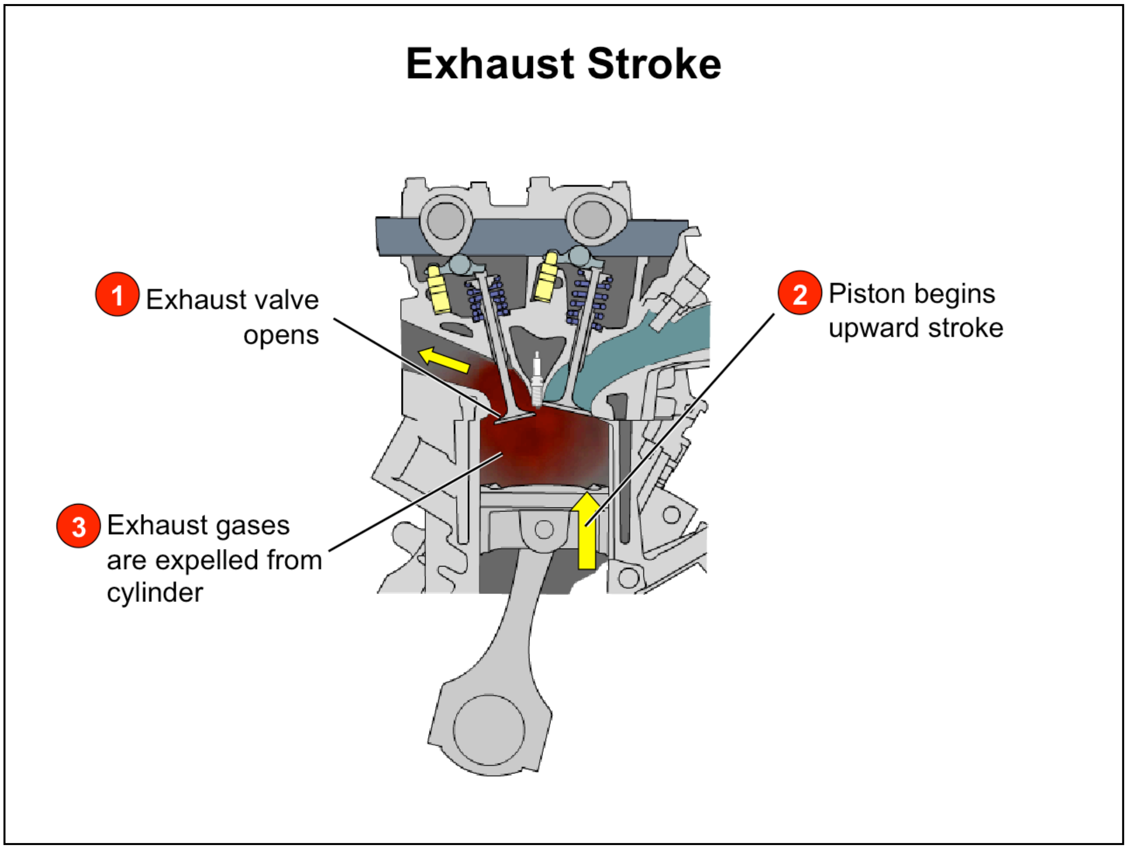
The ECM controls ignition timing based on:

- Engine speed
- Air-fuel ratio
- Engine load

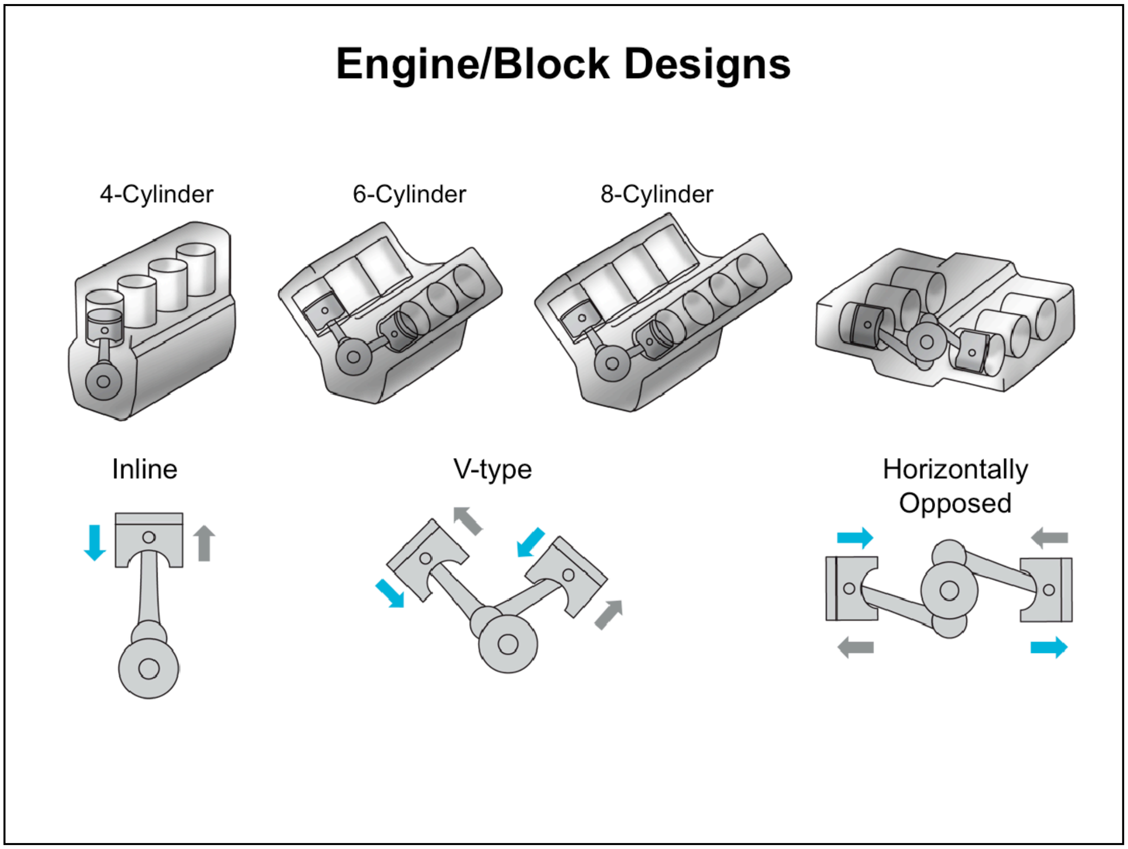



**Combustion (Power) Stroke**

The spark plug ignites the fuel within the cylinder. The burning fuel consumes the available oxygen and creates heat. This heat energy causes the combustion gases within the cylinder to expand forcing the piston downward and rotating the crankshaft to produce rotational power.




**Exhaust Stroke** After the piston reaches the bottom of its stroke, the exhaust valve opens and the piston begins traveling upward, forcing the spent exhaust gasses out of the cylinder. This completes the 4-stroke process and the cycle begins again with the intake stroke.




**Engine and Block Designs**

Adding cylinders to the automotive engine has been a popular way to increase power. With the increase in cylinder count, engineers were tasked with finding the best configuration to fit the engine compartment. Over the years, engineers have developed several options for cylinder arrangement.

**Inline**

Pistons in **inline** engines are all arranged in a **single row**. In years past, inline engines had 4 to as many as 12 cylinders. In current Toyota vehicles, however, 4-cylinder engines are the only models that use the inline design.

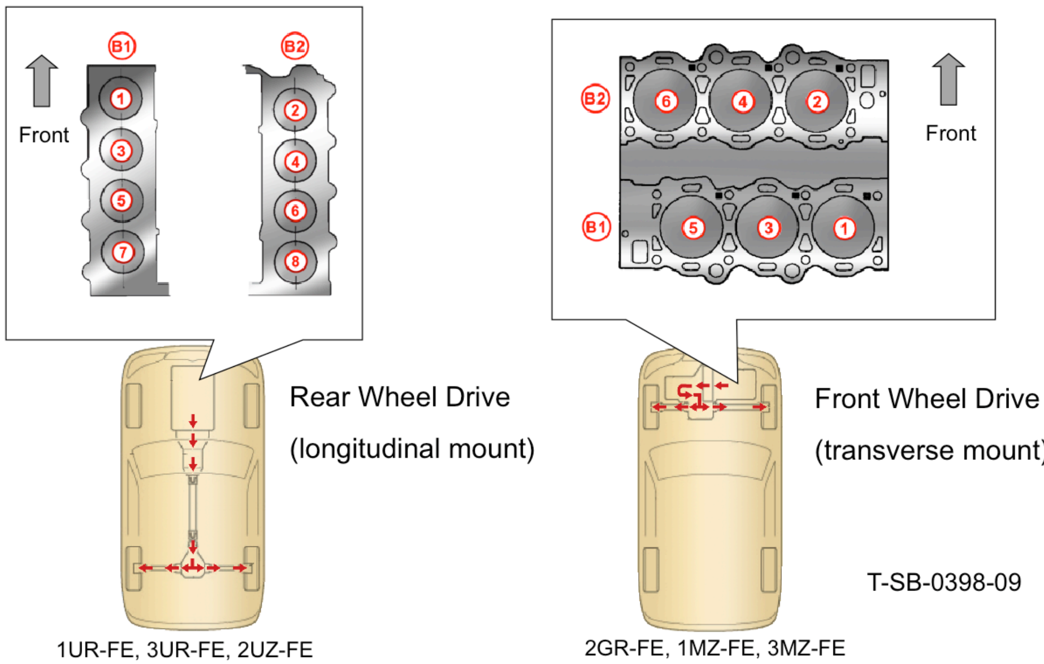
**V-type**

The V-type engine arranges the pistons into two banks that are offset approximately 90º. Compared to in-line engines, V-type engines are more compact and typically lighter. Toyota V-type models are typically V-6 and V-8.

**Horizontally Opposed**

Horizontally opposed engines arrange the pistons in two banks that are offset 180º. This design is sometimes used in air-cooled engines, and the 4 or 6 cylinder models may be referred to as a “flat 4” or “flat  6” engines. Toyota does not currently have any horizontally opposed engines in production.

**Engine Position and Cylinder Identification**




## Engine Position

Toyota engines are mounted in the front of the vehicle. However, the engine can be oriented in the engine compartment two different ways – longitudinally or transversely.

- In rear wheel drive models, the engine is typically mounted longitudinally (crankshaft aligned front-to-back).
- In front wheel drive models, the engine is mounted transversely (crankshaft aligned side-to-side).
- In 4-wheel drive vehicles, the engine is typically mounted longitudinally (similar to rear wheel drive vehicles), with the transfer case redirecting part of the engine's power to the front wheels.

## Cylinder Identification

Many service procedures require you to identify a particular cylinder based on its cylinder number. Although the cylinder-numbering-patterns for longitudinally mounted engines or transversely mounted engines are often similar, you can't assume every vehicle is the same. Always refer to the vehicle's Repair Manual to be certain of cylinder numbers.

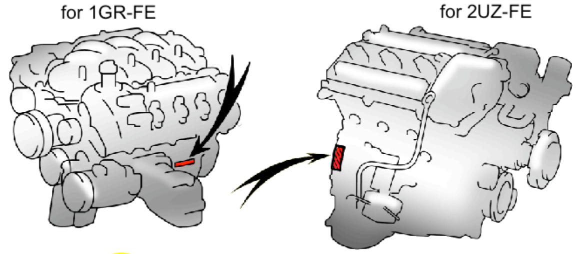
**NOTE**

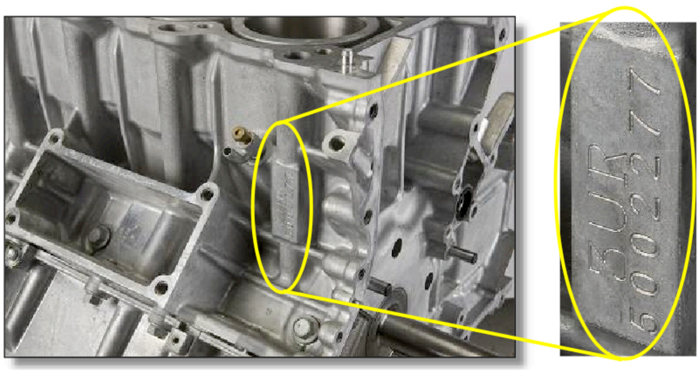
You can also find cylinder identification information in T-SB-0389-09 for the following engines: 1AZ-FE, 2AZ-FE, 2AZ-FE (PZEV), 1GR-FE, 2GR-FE, 2JZ-GE, 1MZ-FE, 3MZ-FE, 1UR-FE, 3UR-FE, 2UZ-FE, 5VZ-FE, and 1ZZ-FE.

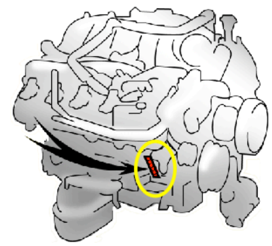
## Engine Serial Number Location

The engine serial number is stamped on the cylinder block of the engine.

See the Repair Manual or relevant TSB for the exact location.






T-SB-0301-08 Engine Serial Number Location

**Engine Serial Number**

Engine serial numbers provide valuable information about where and when that particular engine was manufactured. Currently, the automotive industry, including Toyota, relay on parts sourced from multiple manufacturers and suppliers. If a quality issue arises and the manufacturer needs to evaluate the range of products affected. The serial number is used to determine the plant where it was manufactured and when it was made in the series of production.

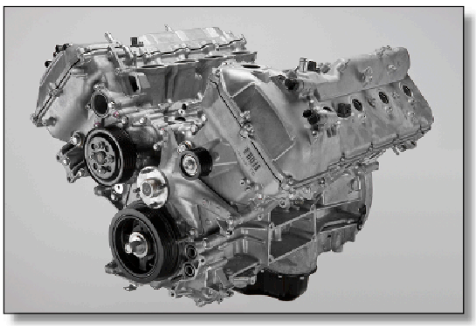
Typically, when a TAS case or product report is opened, the part serial number will be required to process that report. It is important to have this information ready when contacting TAS.

## Engine Decoder

Engine Designation

**3UR - FE**

- 3 = Design Generation
- UR = Engine Family
- FE = Engine Features



Engine Features

- FE = Electronic Fuel Injection
- FE = Narrow Included Valvetrain Angle
- GE = Wide Included Valvetrain Angle
- FNE = Compressed Natural Gas
- FZE = Supercharged
- GTE = Turbocharged
- FXE = Atkinson Cycle
- FBE = Flex Fuel
- FSE = Direct Injection

### Engine Decoder

4 cylinder engines:

- 5S-FE
- 2AZ-FE
- 1NZ-FE
- 3S-FE
- 2TR-FE

6 cylinder engines:

- 1MZ-FE
- 3MZ-FE
- 2GR-FE

8 cylinder engines:

- 2UZ-FE
- 1UR-FE
- 3UR-FE

Engines in series:

- 1AR-FE – 2AR-FE
- 1GR-FE – 2GR-FE
- 1UR-FE – 3UR-FE – 3UR-FBE

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