CHAPTER 10

GASOLINE ENGINE OPERATION, PARTS, AND SPECIFICATIONS

OBJECTIVES

After studying Chapter 10, the reader will be able to:

1. Prepare for Engine Repair (A1) ASE certification test content area "A" (General Engine Diagnosis).
2. Explain how a four-stroke cycle gasoline engine operates.
3. List the various characteristics by which vehicle engines are classified.
4. Discuss how a compression ratio is calculated.
5. Explain how engine size is determined.
6. Describe how turbocharging or supercharging increases engine power.

KEY TERMS

Block (p. 115)
Bore (p. 121)
Boxer (p. 119)
Cam-in-Block Design (p. 119)
Camshaft (p. 119)
Combustion (p. 115)
Combustion Chamber (p. 115)
Compression Ratio (CR) (p. 124)
Connecting Rod (p. 117)
Crankshaft (p. 117)
Cycle (p. 117)
Cylinder (p. 117)
Displacement (p. 121)
Double Overhead Camshaft (DOHC) (p. 119)
Exhaust Valve (p. 117)
External Combustion Engine (p. 115)
Four-Stroke Cycle (p. 117)
Internal Combustion Engine (p. 115)
Mechanical Force (p. 115)
Mechanical Power (p. 115)
Naturally Aspirated (p. 120)
Nonprincipal End (p. 121)
Oil Galleries (p. 116)
Pancake (p. 119)
Piston Stroke (p. 117)
Principal End (p. 121)
Pushrod Engine (p. 119)
Rotary Engine (p. 120)
Single Overhead Camshaft (SOHC) (p. 119)
Stroke (p. 122)
Supercharger (p. 120)
Top Dead Center (TDC) (p. 117)
Turbocharger (p. 120)
Wankel Engine (p. 120)

ENERGY AND POWER

Energy is used to produce power. The chemical energy in fuel is converted to heat by the burning of the fuel at a controlled rate. This process is called **combustion.** If engine combustion occurs within the power chamber, the engine is called an **internal combustion engine.**

NOTE: An **external combustion engine** is an engine that burns fuel outside of the engine itself, such as a steam engine.

Engines used in automobiles are internal combustion heat engines. They convert the chemical energy of the gasoline into heat within a power chamber that is called a **combustion chamber.** Heat energy released in the combustion chamber raises the temperature of the combustion gases within the chamber. The increase in gas temperature causes the pressure of the gases to increase. The pressure developed within the combustion chamber is applied to the head of a piston or to a turbine wheel to produce a usable **mechanical force,** which is then converted into useful **mechanical power.**

ENGINE CONSTRUCTION OVERVIEW

Block

All automotive and truck engines are constructed using a solid frame, called a **block.** A block is constructed of cast iron or aluminum and provides the foundation for most of the engine components and systems. The block is cast and then machined to very close tolerances to allow other parts to be installed.

Rotating Assembly

Pistons are installed in the block and move up and down during engine operation. Pistons are connected to *connecting rods*, which connect the pistons to the crankshaft. The crankshaft converts the up-and-down motion of the piston to rotary motion, which is then transmitted to the drive wheels and propels the vehicle. See Figure 10-1.

Cylinder Heads

All engines use a cylinder head to seal the top of the cylinders, which are in the engine block. The cylinder head also contains valves that allow air and fuel into the cylinder, called intake valves and exhaust valves, which open after combustion to allow the hot gases left over to escape from the engine. Cylinder heads are constructed of cast iron or aluminum and are then machined for the valves and other valve-related components. Cooling passages are formed during the casting process and coolant is circulated around the combustion chamber to keep temperatures controlled. See Figure 10-2.

Intake and Exhaust Manifolds

Air and fuel enters the engine through an intake manifold and exits the engine through the exhaust manifold. Intake manifolds operate cooler than exhaust manifolds and are therefore constructed of nylon reinforced plastic or aluminum. Exhaust manifolds must be able to withstand hot exhaust gases and therefore most are constructed from cast iron.

Cooling System

All engines must have a cooling system to control engine temperatures. While some older engines were air cooled, all current production passenger vehicle engines are cooled by circulating

FIGURE 10-1 The rotating assembly for a V-8 engine that has eight pistons and connecting rods and one crankshaft.

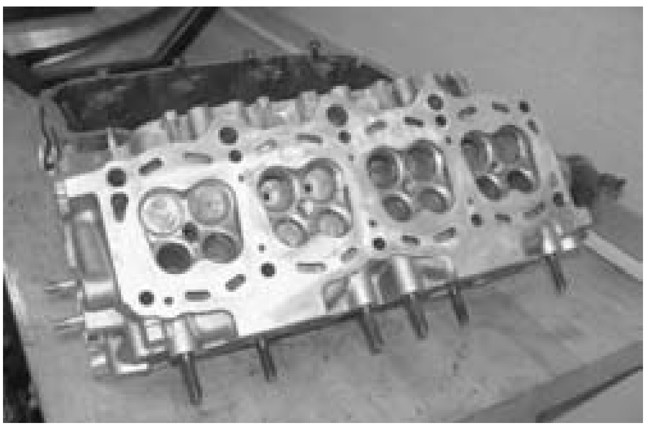


FIGURE 10-2 A cylinder head with four valves per cylinder, two intake valves (larger) and two exhaust valves (smaller).

antifreeze coolant through passages in the block and cylinder head. The coolant picks up the heat from the engine and after the thermostat opens, the water pump circulates the coolant through the radiator where the excess heat is released to the outside air, cooling the coolant. The coolant is continuously circulated through the cooling system and the temperature is controlled by the thermostat. See Figure 10-3.

Lubrication System

All engines contain moving and sliding parts that must be kept lubricated to reduce wear and friction. The oil pan, bolted to the bottom of the engine block, holds 4 to 7 quarts (liters) of oil. An oil pump, which is driven by the engine, forces the oil through the oil filter and then into passages in the crankshaft and block. These passages are called **oil galleries.** The oil is also forced up to the valves and then falls down through openings in the cylinder head and block back into the oil pan. See Figure 10-4.

FIGURE 10-3 The coolant temperature is controlled by the thermostat which opens and allows coolant to flow to the radiator when the temperature reaches the rating temperature of the thermostat.

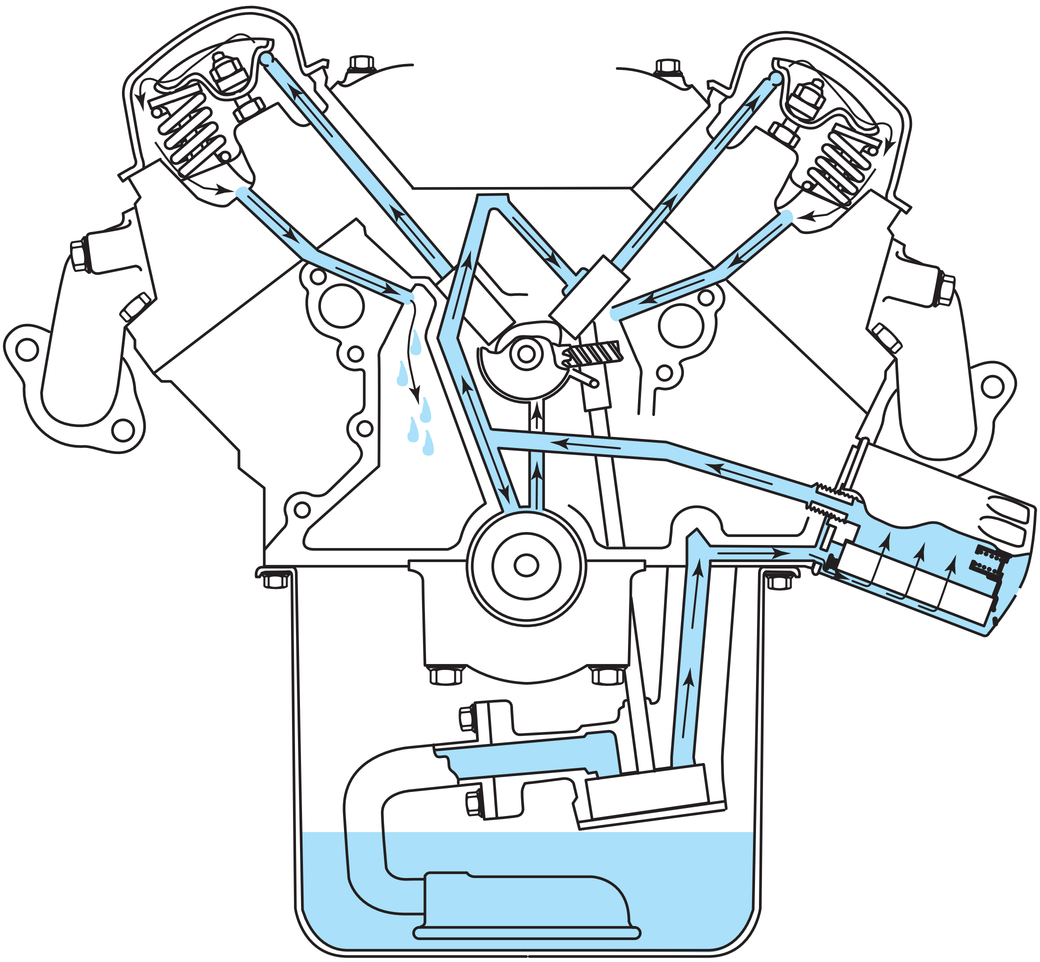


FIGURE 10-4 A typical lubrication system, showing the oil pan, oil pump, oil filter, and oil passages.

Fuel System and Ignition System

All engines require fuel and an ignition system to ignite the fuel–air mixture in the cylinders. The fuel system includes the following components:

- Fuel tank where fuel is stored
- Fuel filter and lines
- Fuel injectors, which spray fuel into the intake manifold or directly into the cylinder, depending on the type of system used

The ignition system is designed to take 12 volts from the battery and convert it to 5,000 to 40,000 volts needed to jump the gap of a spark plug. Spark plugs are threaded into the cylinder head of each cylinder, and when the spark occurs, it ignites the air–fuel mixture in the cylinder creating pressure and forcing the piston down in the cylinder. The components included on the ignition system include:

- Spark plugs
- Ignition coils
- Ignition control module (ICM)
- Associated wiring

FOUR-STROKE CYCLE OPERATION

Most automotive engines use the four-stroke cycle of events, begun by the starter motor which rotates the engine. The four-stroke cycle is repeated for each cylinder of the engine. See Figure 10-5.

- **Intake stroke.** The **intake valve** is open and the piston inside the cylinder travels downward, drawing a mixture of air and fuel into the cylinder.
- **Compression stroke.** As the engine continues to rotate, the intake valve closes and the piston moves upward in the cylinder, compressing the air–fuel mixture.
- **Power stroke.** When the piston gets near the top of the cylinder (called **top dead center [TDC]**), the spark at the spark plug ignites the air–fuel mixture, which forces the piston downward.
- **Exhaust stroke.** The engine continues to rotate, and the piston again moves upward in the cylinder. The exhaust valve opens, and the piston forces the residual burned gases out of the **exhaust valve** and into the exhaust manifold and exhaust system.

This sequence repeats as the engine rotates. To stop the engine, the electricity to the ignition system is shut off by the ignition switch.

A piston that moves up and down, or reciprocates, in a **cylinder** can be seen in this illustration. The piston is attached to a **crankshaft** with a **connecting rod.** This arrangement allows the piston to reciprocate (move up and down) in the cylinder as the crankshaft rotates. See Figure 10-6 on page 119.

The combustion pressure developed in the combustion chamber at the correct time will push the piston downward to rotate the crankshaft.

THE 720° CYCLE

Each cycle of events requires that the engine crankshaft make two complete revolutions or 720° (360° × 2 = 720°). The greater the number of cylinders, the closer together the power strokes occur. To find the angle between cylinders of an engine, divide the number of cylinders into 720°.

Angle with three cylinders = 720°/3 = 240°
Angle with four cylinders = 720°/4 = 180°
Angle with five cylinders = 720°/5 = 144°
Angle with six cylinders = 720°/6 = 120°
Angle with eight cylinders = 720°/8 = 90°
Angle with ten cylinders = 720°/10 = 72°

This means that in a four-cylinder engine, a power stroke occurs at every 180° of the crankshaft rotation (every 1/2 rotation). A V-8 is a much smoother operating engine because a power stroke occurs twice as often (every 90° of crankshaft rotation).

Engine cycles are identified by the number of piston strokes required to complete the cycle. A **piston stroke** is a one-way piston movement between the top and bottom of the cylinder. During one stroke, the crankshaft revolves 180° (1/2 revolution). A **cycle** is a complete series of events that continually repeat. Most automobile engines use a **four-stroke cycle.**

ENGINE CLASSIFICATION AND CONSTRUCTION

Engines are classified by several characteristics including:

- **Number of strokes.** Most automotive engines use the four-stroke cycle.
- **Cylinder arrangement.** An engine with more cylinders is smoother operating because the power pulses produced by the power strokes are more closely spaced. An inline engine places all cylinders in a straight line. Four-, five-, and six-cylinder engines are commonly manufactured inline engines. A V-type engine, such as a V-6 or V-8, has the number of cylinders split and built into a V-shape. See Figure 10-7 on page 119. Horizontally opposed four- and

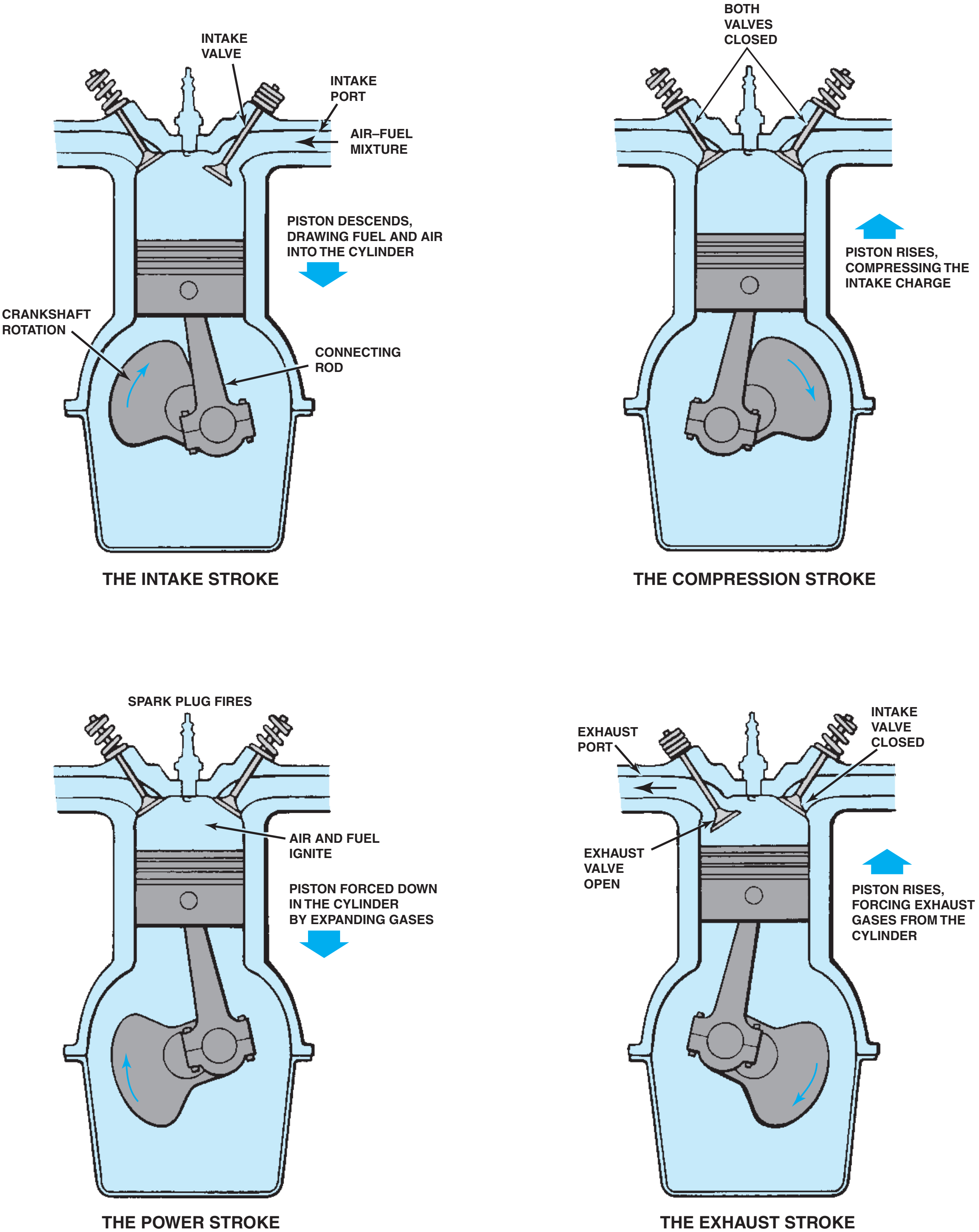


FIGURE 10-5 The downward movement of the piston draws the air–fuel mixture into the cylinder through the intake valve on the intake stroke. On the compression stroke, the mixture is compressed by the upward movement of the piston with both valves closed. Ignition occurs at the beginning of the power stroke, and combustion drives the piston downward to produce power. On the exhaust stroke, the upward-moving piston forces the burned gases out the open exhaust valve.

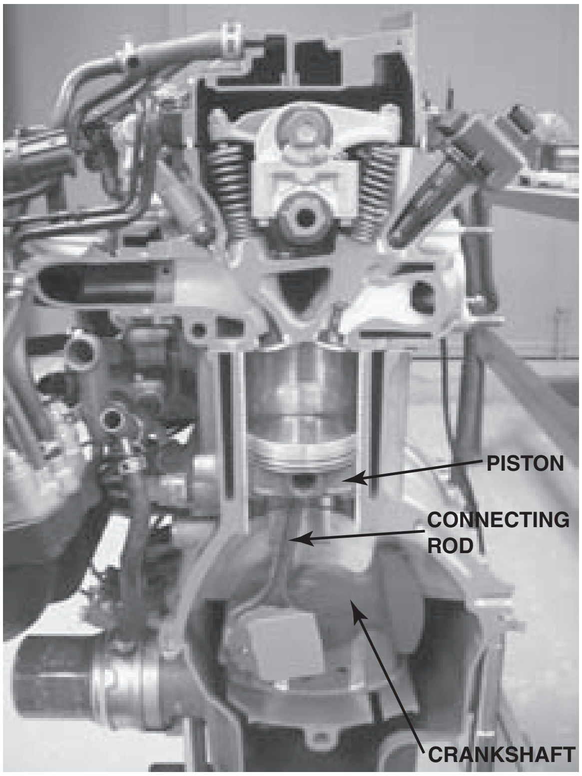


FIGURE 10-6 Cutaway of an engine showing the cylinder, piston, connecting rod, and crankshaft.

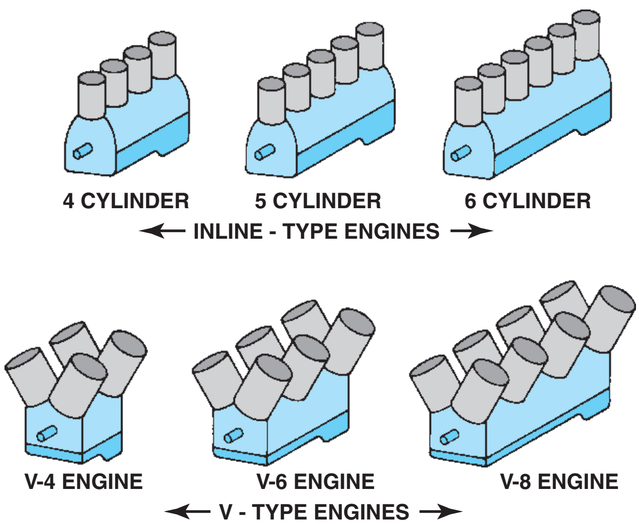


FIGURE 10-7 Automotive engine cylinder arrangements.

six-cylinder engines have two banks of cylinders that are horizontal, resulting in a low engine. This style of engine is used in Porsche and Subaru engines and is often called the **boxer** or **pancake** engine design. See Figure 10-8.

- **Longitudinal or transverse mounting.** Engines may be mounted either parallel with the length of the vehicle (longitudinally) or crosswise (transversely). See Figures 10-9 and 10-10. The same engine may be mounted in various vehicles in either direction.

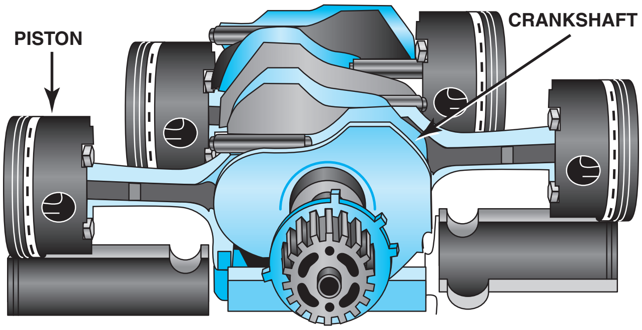


FIGURE 10-8 A horizontally opposed engine design helps to lower the vehicle's center of gravity.

NOTE: Although it might be possible to mount an engine in different vehicles both longitudinally and transversely, the engine component parts may not be interchangeable. Differences can include different engine blocks and crankshafts, as well as different water pumps.

- **Valve and camshaft number and location.** The number of valves and the number and location of camshafts are a major factor in engine operation. A typical older-model engine uses one intake valve and one exhaust valve per cylinder. Many newer engines use two intake and two exhaust valves per cylinder. The valves are opened by a **camshaft.** For high-speed engine operation, the camshaft should be overhead (over the valves). Some engines use one camshaft for the intake valves and a separate camshaft for the exhaust valves. When the camshaft is located in the block, the valves are operated by lifters, pushrods, and rocker arms. See Figure 10-11. This type of engine is called a **pushrod engine** or **cam-in-block design.** An overhead camshaft engine has the camshaft above the valves in the cylinder head. When one overhead camshaft is used, the design is called a **single overhead camshaft (SOHC)** design. When two overhead camshafts are used, the design is called a **double overhead camshaft (DOHC)** design. See Figures 10-12 and 10-13 on page 121.

NOTE: A V-type engine uses two banks or rows of cylinders. An SOHC design therefore uses two camshafts, but only one camshaft per bank (row) of cylinders. A DOHC V-6, therefore, has four camshafts, two for each bank.

- **Type of fuel.** Most engines operate on gasoline, whereas some engines are designed to operate on methanol, natural gas, propane, or diesel fuel.

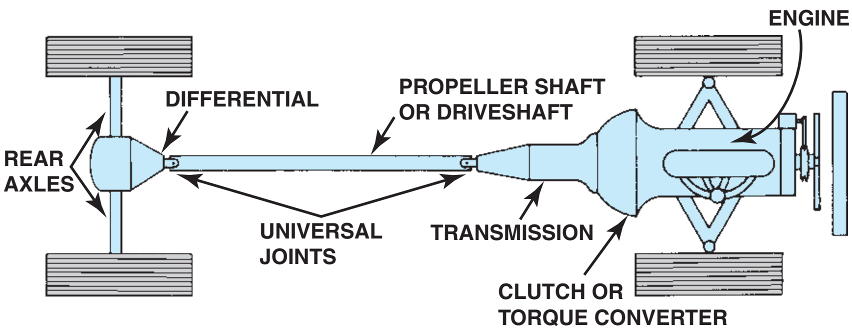


FIGURE 10-9 A longitudinally mounted engine drives the rear wheels through a transmission, driveshaft, and differential assembly.

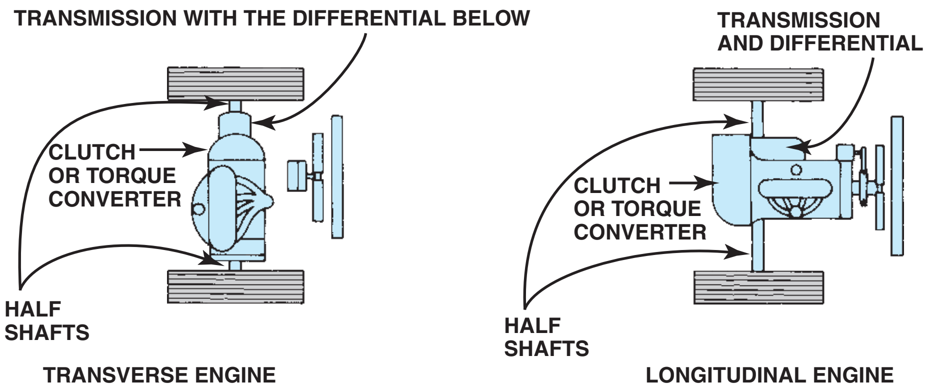


FIGURE 10-10 Two types of front-engine, front-wheel drive.

FIGURE 10-11 Cutaway of a V-8 engine showing the lifters, pushrods, roller rocker arms, and valves.

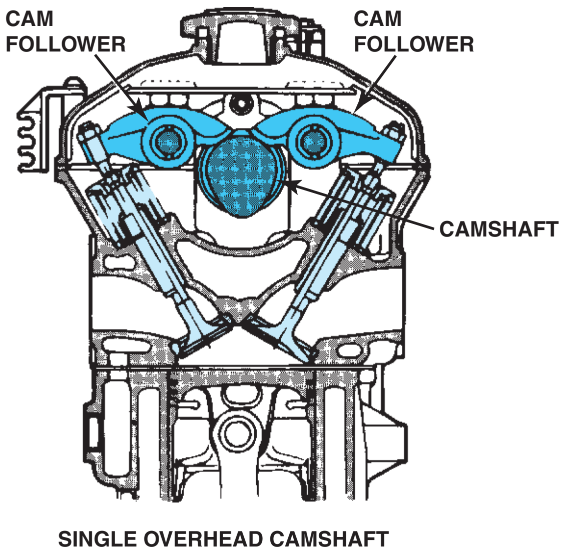
- **Cooling method.** Most engines are liquid cooled, but some older models were air cooled.
- **Type of induction pressure.** If atmospheric air pressure is used to force the air–fuel mixture into the cylinders, the engine is called **naturally aspirated.** Some engines use a **turbocharger** or **supercharger** to force the air–fuel mixture into the cylinder for even greater power.

FREQUENTLY ASKED QUESTION

WHAT IS A ROTARY ENGINE?

A successful alternative engine design is the **rotary engine,** also called the **Wankel engine** after its inventor. The Mazda RX-7 and RX-8 represents the only long-term use of the rotary engine. The rotating combustion chamber engine runs very smoothly, and it produces high power for its size and weight.

The basic rotating combustion chamber engine has a triangular-shaped rotor turning in a housing. The housing is in the shape of a geometric figure called a two-lobed epitrochoid. A seal on each corner, or apex, of the rotor is in constant contact with the housing, so the rotor must turn with an eccentric motion. This means that the center of the rotor moves around the center of the engine. The eccentric motion can be seen in Figure 10-14 on page 122.



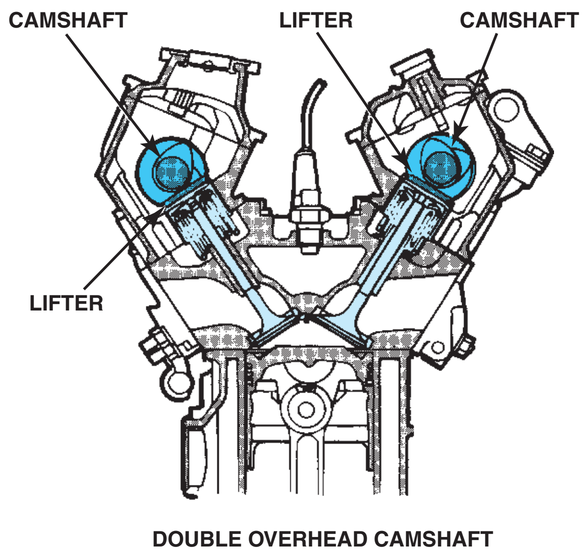


FIGURE 10-12 SOHC engines usually require additional components such as a rocker arm to operate all of the valves. DOHC engines often operate the valves directly.

FIGURE 10-13 A dual overhead camshaft (DOHC) V-8 engine with part of the cam cover cut away.

ENGINE ROTATION DIRECTION

The SAE standard for automotive engine rotation is counterclockwise (CCW) as viewed from the flywheel end (clockwise as viewed from the front of the engine). The flywheel end of the engine is the end to which the power is applied to drive the vehicle. This is called the **principal end** of the engine. The **nonprincipal end** of the engine is opposite the principal end and is generally referred to as the *front* of the engine, where the accessory belts are used. See Figure 10-15 on page 123.

In most rear-wheel-drive vehicles, therefore, the engine is mounted longitudinally with the principal end at the rear of the engine. Most transversely mounted engines also adhere to the same standard for direction of rotation. Many Honda engines and some marine applications may differ from this standard.

FREQUENTLY ASKED QUESTION

WHERE DOES AN ENGINE STOP?

When the ignition system is turned off, the firing of the spark plugs stops and the engine will rotate until it stops due to the inertia of the rotating parts. The greatest resistance that occurs in the engine happens during the compression stroke. It has been determined that an engine usually stops when one of the cylinders is about 70 degrees before top dead center (BTDC) on the compression stroke with a variation of plus or minus 10 degrees.

This explains why technicians discover that the starter ring gear is worn at two locations on a four-cylinder engine. The engine stops at one of the two possible places depending on which cylinder is on the compression stroke.

BORE

The diameter of a cylinder is called the **bore.** The larger the bore, the greater the area on which the gases have to work. Pressure is measured in units, such as pounds per square inch (PSI). The greater the area (in square inches), the higher the

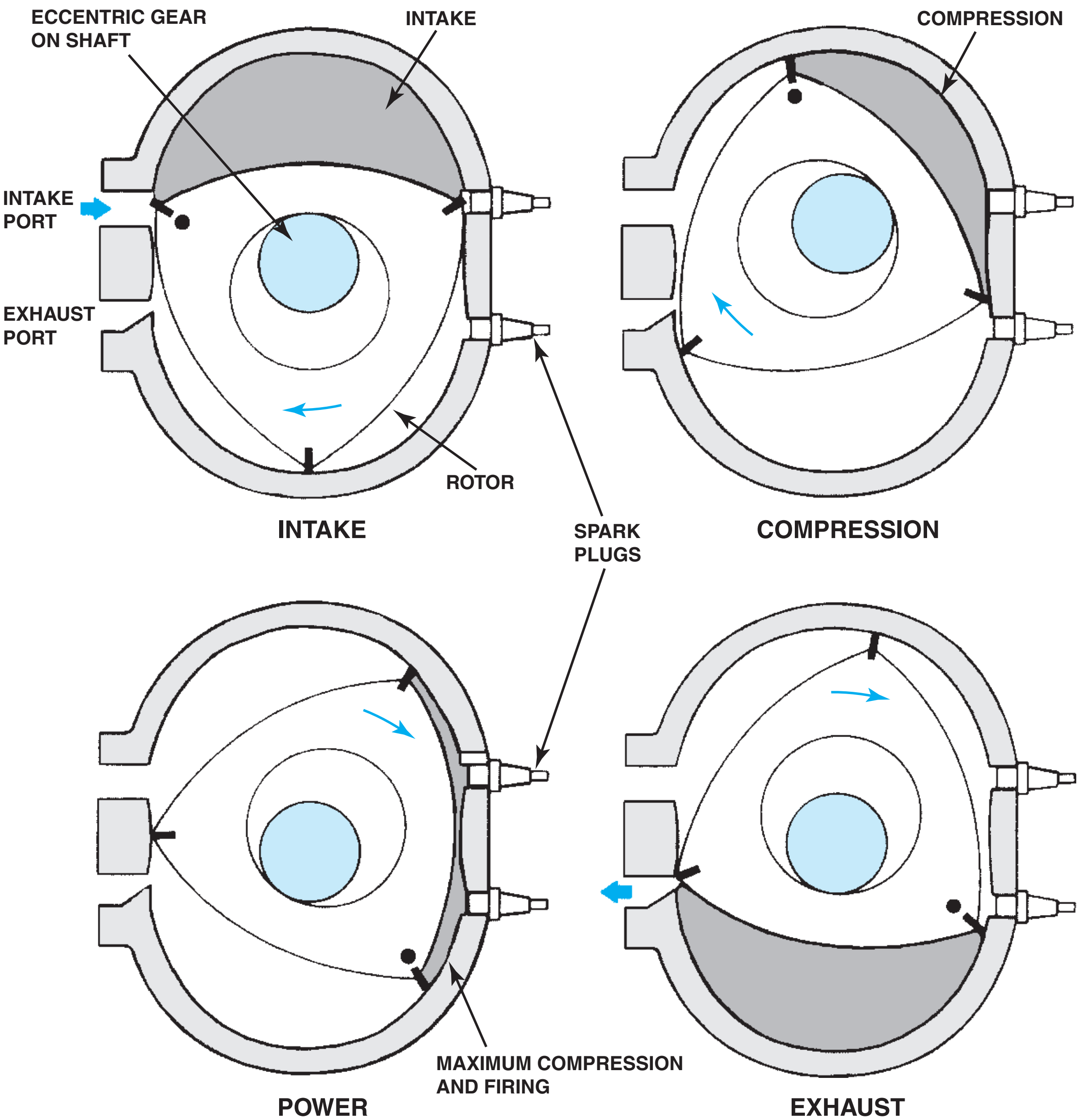


FIGURE 10-14 Rotary engine operates on the four-stroke cycle but uses a rotor instead of a piston and crankshaft to achieve intake, compression, power, and exhaust stroke.

force exerted by the pistons to rotate the crankshaft. See Figure 10-16.

STROKE

The distance the piston travels down in the cylinder is called the **stroke.** The longer this distance is, the greater the amount of air–fuel mixture that can be drawn into the cylinder. The more air–fuel mixture inside the cylinder, the more force will result when the mixture is ignited.

ENGINE DISPLACEMENT

Engine size is described as displacement. **Displacement** is the cubic inch (cu. in.) or cubic centimeter (cc) volume displaced or swept by all of the pistons. A liter (L) is equal to 1,000 cubic centimeters; therefore, most engines today are identified by their displacement in liters.

1 L = 1,000 cc
1 L = 61 cu. in.
1 cu. in. = 16.4 cc

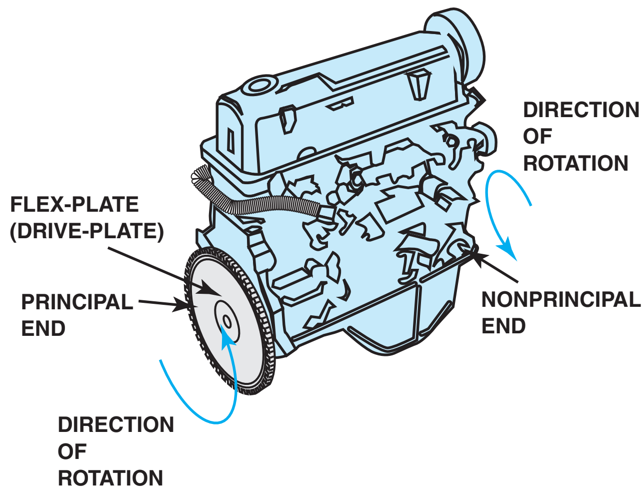


FIGURE 10-15 Inline four-cylinder engine showing principal and nonprincipal ends. Normal direction of rotation is clockwise (CW) as viewed from the front or accessory belt end (nonprincipal end).

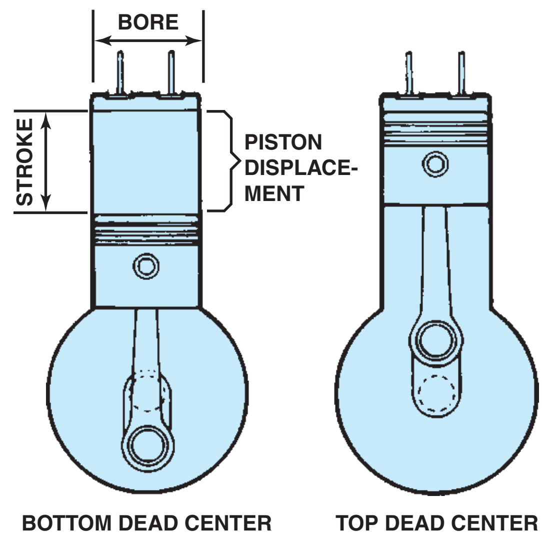


FIGURE 10-16 The bore and stroke of pistons are used to calculate an engine's displacement.

The formula to calculate the displacement of an engine is basically the formula for determining the volume of a cylinder multiplied by the number of cylinders. However, because the formula has been publicized in many different forms, it seems somewhat confusing. Regardless of the method used, the results will be the same. The easiest and most commonly used formula is

Bore × bore × stroke × 0.7854 × number of cylinders

For example, take a 6-cylinder engine where, bore = 4.000 in., stroke = 3.000 in. Applying the formula,

4.000 in. × 4.000 in. ×3.000 in. ×0.7854 × 6 = 226 cu. in.

Engine Size Conversion Chart Liters to Cubic Inches

Liters	Cubic Inches	Liters	Cubic Inches
1.0	61	4.2	255/258
1.3	79	4.3	260/262/265
1.4	85	4.4	267
1.5	91	4.5	273
1.6	97/98	4.6	280/281
1.7	105	4.8	292
1.8	107/110/112	4.9	300/301
1.9	116	5.0	302/304/305/307
2.0	121/122	5.2	318
2.1	128	5.3	327
2.2	132/133/134/135	5.4	330
2.3	138/140	5.7	350
2.4	149	5.8	351
2.5	150/153	6.0	366/368
2.6	156/159	6.1	370
2.8	171/173	6.2	381
2.9	177	6.4	389/390/391
3.0	181/182/183	6.5	396
3.1	191	6.6	400
3.2	196	6.9	420
3.3	200/201	7.0	425/427/428/429
3.4	204	7.2	440
3.5	215	7.3	445
3.7	225	7.4	454
3.8	229/231/232	7.5	460
3.9	239/240	7.8	475/477
4.0	241/244	8.0	488
4.1	250/252	8.8	534

Because 1 cubic inch equals 16.4 cubic centimeters, this engine displacement equals 3,706 cubic centimeters or, rounded to 3,700 cubic centimeters, 3.7 liters.

How to convert cubic inches to liters: 61.02 cubic inches = 1 liter

Example

From liter to cubic inch—5.0 L × 61.02 = 305 CID
From cubic inch to liter—305 ÷ 61.02 = 5.0 L

Engine Size versus Horsepower

The larger the engine, the more power the engine is capable of producing. Several sayings are often quoted about engine size:

"There is no substitute for cubic inches."
"There is no replacement for displacement."

Although a large engine generally uses more fuel, making an engine larger is often the easiest way to increase power.

COMPRESSION RATIO

The compression ratio of an engine is an important consideration when rebuilding or repairing an engine. **Compression ratio (CR)** is the ratio of the volume in the cylinder above the piston when the piston is at the bottom of the stroke to the volume in the cylinder above the piston when the piston is at the top of the stroke. See Figure 10-17.

If Compression Is Lower	*If Compression Is Higher*
Lower power	Higher power possible
Poorer fuel economy	Better fuel economy
Easier engine cranking	Harder to crank engine, especially when hot
More advanced ignition timing possible without spark knock (detonation)	Less ignition timing required to prevent spark knock (detonation)

$$CR = \frac{\text{Volume in cylinder with piston at bottom of cylinder}}{\text{Volume in cylinder with piston at top center}}$$

See Figure 10-18.

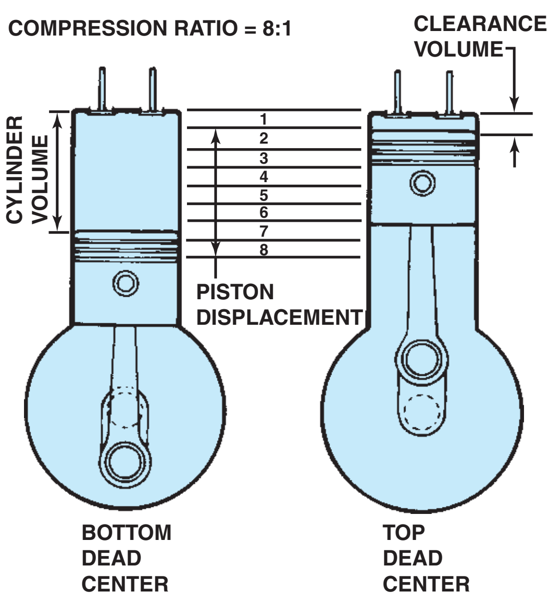


FIGURE 10-17 Compression ratio is the ratio of the total cylinder volume (when the piston is at the bottom of its stroke) to the clearance volume (when the piston is at the top of its stroke).

TECH TIP

ALL 3.8-LITER ENGINES ARE NOT THE SAME!

Most engine sizes are currently identified by displacement in liters. However, not all 3.8-liter engines are the same. See, for example, the following table:

Engine	*Displacement*
Chevrolet-built 3.8-L, V-6	229 cu. in.
Buick-built 3.8-L, V-6 (also called 3,800 cc)	231 cu. in.
Ford-built 3.8-L, V-6	232 cu. in.

The exact conversion from liters (or cubic centimeters) to cubic inches is 231.9 cubic inches. However, due to rounding of exact cubic-inch displacement and rounding of the exact cubic-centimeter volume, several entirely different engines can be marketed with the exact same liter designation. To reduce confusion and reduce the possibility of ordering incorrect parts, the vehicle identification number (VIN) should be noted for the vehicle being serviced. The VIN should be visible through the windshield on all vehicles. Since 1980, the *engine* identification number or letter is usually the eighth digit or letter from the left.

Smaller, 4-cylinder engines can also cause confusion because many vehicle manufacturers use engines from both overseas and domestic manufacturers. Always refer to service manual information to be assured of correct engine identification.

For example: What is the compression ratio of an engine with 50.3-cu. in. displacement in one cylinder and a combustion chamber volume of 6.7 cu. in.?

$$CR = \frac{50.3 + 6.7 \text{ cu. in.} = 57.0}{6.7 \text{ cu. in.}} = 8.5$$

THE CRANKSHAFT DETERMINES THE STROKE

The stroke of an engine is the distance the piston travels from top dead center (TDC) to bottom dead center (BDC). This distance is determined by the throw of the crankshaft. The throw is the distance from the centerline of the crankshaft to the centerline of the crankshaft rod journal. The throw is one-half of the stroke. See Figure 10-19 for an example of a crankshaft as installed in a GM V-6 engine.

If the crankshaft is replaced with one with a greater stroke, the pistons will be pushed up over the height of the top of the block (deck). The solution to this problem is to install replacement pistons with the piston pin relocated higher on the piston. Another alternative is to replace the connecting rod with a shorter one to prevent the piston from traveling too far up in the cylinder. Changing the connecting rod length does *not* change the stroke of an engine. Changing the connecting rod only changes the position of the piston in the cylinder.

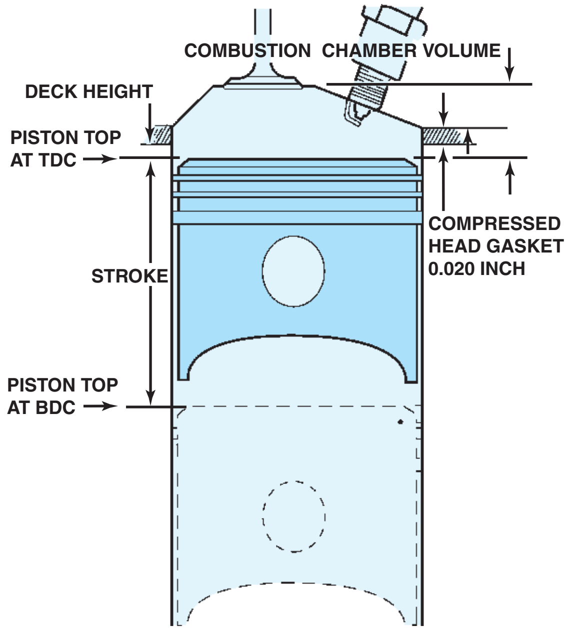


FIGURE 10-18 Combustion chamber volume is the volume above the piston with the piston at top dead center.

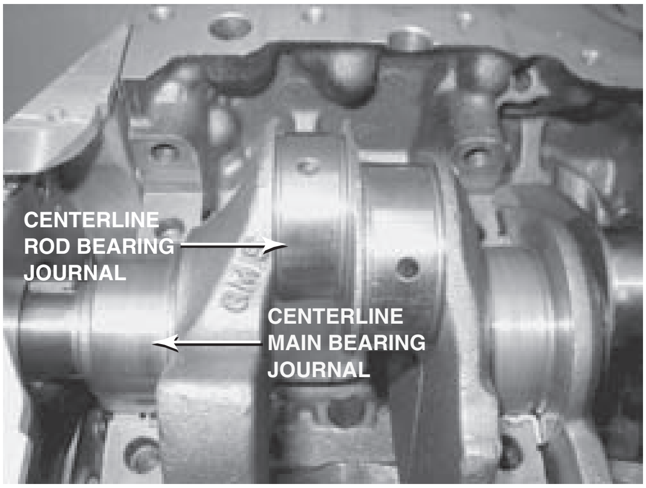


FIGURE 10-19 The distance between the centerline of the main bearing journal and the centerline of the connecting rod journal determines the stroke of the engine. This photo is a little unusual because this is from a V-6 with a splayed crankshaft used to even out the impulses on a 90°, V-6 engine design.

TORQUE

Torque is the term used to describe a rotating force that may or may not result in motion. Torque is measured as the amount of force multiplied by the length of the lever through which it acts. If a one-foot-long wrench is used to apply 10 pounds of force to the end of the wrench to turn a bolt, then you are exerting 10 pound-feet of torque. See Figure 10-20.

The metric unit for torque is Newton-meters because Newton is the metric unit for force and the distance is expressed in meters.

one pound-foot = 1.3558 Newton-meters
one Newton-meter = 0.7376 pound-foot

POWER

The term power means the rate of doing work. Power equals work divided by time. Work is achieved when a certain amount of mass (weight) is moved a certain distance by a force. If the object is moved in 10 seconds or 10 minutes does not make a difference in the amount of work accomplished, but it does affect the amount of power needed. Power is expressed in units of foot-pounds per minute.

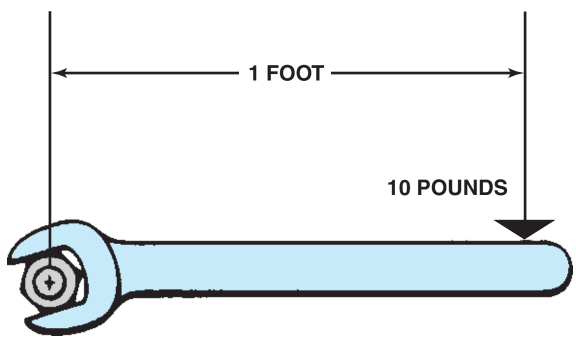


FIGURE 10-20 Torque is a twisting force equal to the distance from the pivot point times the force applied expressed in units called pound-feet (lb-ft) or Newton-meters (N-m).

TECH TIP

QUICK-AND-EASY ENGINE EFFICIENCY CHECK

A good, efficient engine is able to produce a lot of power from little displacement. A common rule of thumb is that an engine is efficient if it can produce *1 horsepower per cubic inch* of displacement. Many engines today are capable of this feat, such as the following:

Ford	4.6 L V-8 (281 cu. in.)—305 hp
Chevrolet	3.4 L V-6 (207 cu. in.)—210 hp
Chrysler	3.5 L V-6 (214 cu. in.)—214 hp
Acura	3.2 L V-6 (195 cu. in.)—270 hp

An engine is very powerful for its size if it can produce *100 hp per liter*. This efficiency goal is harder to accomplish. Most factory stock engines that can achieve this feat are supercharged or turbocharged.

HORSEPOWER AND ALTITUDE

Because the density of the air is lower at high altitude, the power that a normal engine can develop is greatly reduced at high altitude. According to SAE conversion factors, a nonsupercharged or nonturbocharged engine loses about 3% of its power for every 1,000 feet (300 meters [m]) of altitude.

Therefore, an engine that develops 150 brake horsepower at sea level will only produce about 85 brake horsepower at the top of Pike's Peak in Colorado at 14,110 feet (4,300 meters). Supercharged and turbocharged engines are not as greatly affected by altitude as normally aspirated engines. Normally aspirated, remember, means engines that breathe air at normal atmospheric pressure.

SUMMARY

1. The four strokes of the four-stroke cycle are intake, compression, power, and exhaust.
2. Engines are classified by number and arrangement of cylinders and by number and location of valves and camshafts, as well as by type of mounting, fuel used, cooling method, and induction pressure.
3. Most engines rotate clockwise as viewed from the front (accessory) end of the engine. The SAE standard is counterclockwise as viewed from the principal (flywheel) end of the engine.
4. Engine size is called displacement and represents the volume displaced or swept by all of the pistons.

REVIEW QUESTIONS

1. Name the strokes of a four-stroke cycle.
2. If an engine at sea level produces 100 horsepower, how many horsepower would it develop at 6,000 feet of altitude?

CHAPTER QUIZ

1. All overhead valve engines _____.
   a. Use an overhead camshaft
   b. Have the overhead valves in the head
   c. Operate by the two-stroke cycle
   d. Use the camshaft to close the valves
2. An SOHC V-8 engine has how many camshafts?
   a. One
   b. Two
   c. Three
   d. Four
3. The coolant flow through the radiator is controlled by the _____.
   a. Size of the passages in the block
   b. Thermostat
   c. Cooling fan(s)
   d. Water pump
4. Torque is expressed in units of _____.
   a. Pound-feet
   b. Foot-pounds
   c. Foot-pounds per minute
   d. Pound-feet per second
5. Horsepower is expressed in units of _____.
   a. Pound-feet
   b. Foot-pounds
   c. Foot-pounds per minute
   d. Pound-feet per second
6. A normally aspirated automobile engine loses about _____ power per 1,000 feet of altitude.
   a. 1%
   b. 3%
   c. 5%
   d. 6%
7. One cylinder of an automotive four-stroke cycle engine completes a cycle every _____.
   a. 90°
   b. 180°
   c. 360°
   d. 720°
8. How many rotations of the crankshaft are required to complete each stroke of a four-stroke cycle engine?
   a. One-fourth
   b. One-half
   c. One
   d. Two
9. A rotating force is called _____.
   a. Horsepower
   b. Torque
   c. Combustion pressure
   d. Eccentric movement
10. Technician A says that a crankshaft determines the stroke of an engine. Technician B says that the length of the connecting rod determines the stroke of an engine. Which technician is correct?
    a. Technician A only
    b. Technician B only
    c. Both Technicians A and B
    d. Neither Technician A nor B