20 Automotive Fuels, Gasoline and Diesel Combustion

After studying this chapter, you will be able to:

- Summarize how crude oil is converted into gasoline, diesel fuel, liquefied petroleum gas, and other products.
- Describe properties of gasoline and diesel fuel.
- Explain octane and octane ratings.
- Describe normal and abnormal combustion of gasoline and diesel fuel.
- Summarize the properties of alternative fuels.
- Correctly answer ASE certification test questions on automotive fuels and combustion.

An automotive engine burns ***fuel*** as a source of energy. Various types of fuel will burn in an engine: gasoline, diesel fuel, gasohol, alcohol, liquefied petroleum gas, and other alternative fuels.

An automotive technician must understand how fuel burns inside an engine. ***Combustion*** (burning) is a primary factor controlling fuel economy, power, emissions, and engine service life.

Petroleum (Crude Oil)

Crude oil, or ***petroleum***, is oil taken directly out of the ground. It is used to make gasoline, diesel fuel, liquefied petroleum gas, and many nonfuel materials (asphalt, motor oil, etc.). **Figure 20-1** shows some of the products made from crude oil.

Natural crude oil is a mixture of *semisolids* (neither solid nor liquid), liquids, and gases. Chemically, crude oil consists of highly flammable hydrocarbons.

Hydrocarbons are chemical mixtures of about 12% hydrogen (flammable gas vapor) and 82% carbon (heavy, black solid). Crude oil also contains sulfur, nitrogen, metals, and saltwater. These elements must be removed.

Processing Crude Oil

Crude oil deposits are contained inside the earth. Oil companies perform ***exploration tests*** (seismic studies, surface mapping, and test drilling) to find oil. After determining where oil might be located, a drill crew bores a hole thousands of feet into the ground. A huge steel derrick is used for the drilling operation. It has a cutting bit capable of passing through dirt, sand, and rock. See **Figure 20-2.**

Once the oil deposit has been reached, the oil is pumped to the surface. Then, the oil is sent to the refinery. The ***refinery*** converts the crude oil into more useful substances.

Distillation is the first conversion process. During distillation, a ***fractionating tower*** is used to break the crude oil down into different parts, or fractions (LPG, gasoline, kerosene, fuel oil, and lubricating oils). Look at **Figure 20-3.** After distillation, other processes purify these products.

Gasoline

Gasoline is the most common type of automotive fuel. It is an abundant and highly flammable part of crude oil. Extra chemicals, called additives (detergents, antioxidants, etc.), are mixed into gasoline to improve its operating characteristics.

Antiknock additives slow down the burning of gasoline. This helps prevent ***engine ping,*** or ***knock*** (knocking sound produced by abnormal, rapid combustion).

Gasoline Octane Ratings

The ***octane rating*** of gasoline is a measurement of the fuel's ability to resist knock or ping. A high octane rating indicates the fuel will *not* knock or ping easily. High-octane gasoline should be used in high-compression engines and turbocharged engines. Low-octane gasoline is suitable for low-compression engines.

Octane numbers give the antiknock value of gasoline. Gasoline with a high octane number (91, for example) will resist knock and ping better than gasoline with a low octane number (87, for example).

Octane numbers are given on the gas station pump, **Figure 20-4.** Automakers recommend octane ratings of fuel for their engines. The owner's manual will give the octane number recommended for the car's engine. Use a fuel with an octane number as high as or higher than the automaker's recommendations. **Figure 20-5** summarizes several factors that control engine octane requirements.

In the past, tetraethyl lead (a heavy metal) was used to increase the octane rating of gasoline. It was phased out because it posed a health hazard.

Octane enhancers, or ***oxygenates***, are now used as blending components in gasoline to increase octane levels and reduce engine knock. Oxygenates are alcohols that are made up of hydrogen, carbon, and oxygen. Examples of octane enhancers include toluene, ethanol, and MTBE.

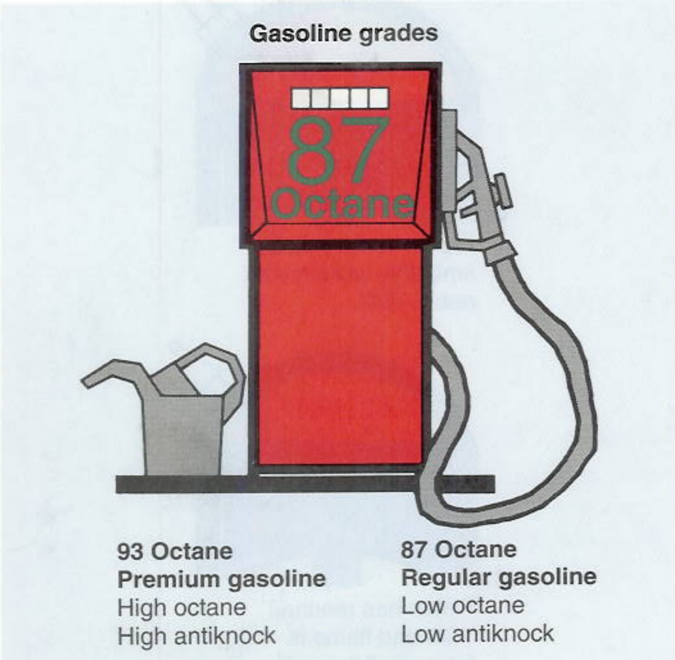

Figure 20-4. The gasoline grade indicates the antiknock value of gasoline.

Gasoline Combustion

For gasoline (or any other fuel) to burn properly, it must be mixed with the right amount of air. The mixture must then be compressed and ignited. The resulting combustion produces heat, expansion of gases, and pressure. The pressure pushes down on the piston to rotate the crankshaft. Refer to **Figure 20-6.**

Normal Gasoline Combustion

Normal gasoline combustion occurs when the spark plug ignites the fuel and burning progresses smoothly through the fuel mixture. Maximum cylinder pressure should be produced a few degrees of crank rotation after piston TDC on the power stroke. **Figure 20-7** illustrates normal gasoline combustion:

A— A spark at the spark plug starts the fuel burning. A small ball of flame forms around the tip of the plug. The piston is moving up in the cylinder, compressing the fuel mixture.

Octane requirement factors	
Octane number requirement tends to go *up* when: 1. Ignition timing is advanced. 2. Air density rises due to supercharging, a larger throttle opening, or higher barometric pressures. 3. Humidity or moisture content of air decreases. 4. Inlet air temperature goes up. 5. Lean fuel-air ratios. 6. Compression ratio is increased. 7. Coolant temperature is raised. 8. Antifreeze (glycol) engine coolant is used. 9. Combustion chamber design provides little or no quench area. 10. Vehicle weight is increased. 11. Engine loading is increased, such as when climbing a grade, pulling a trailer, or increasing wind grade, or increasing wind resistance with a car-top carrier.	Octane number requirement tends to go *down* when: 1. Car is operated at higher altitudes (lower barometric pressure). 2. Fuel-air ratio is richer or leaner than that producing maxium knock. 3. Spark plug location in combustion chamber provides shortest path of flame travel. 4. Combustion chamber design gives maximum turbulence of fuel-air charge. 5. Compression ratio is lowered. 6. Exhaust gas recycle system operates at part-throttle. 7. Ignition timing retard devices are used. 8. Humidity of the air increases. 9. Ignition timing is retarded. 10. Inlet air temperature is decreased. 11. Reduced engine loads are employed.

Figure 20-5. Various factors that control octane requirements. (Ethyl Corp.)

change the air-fuel ratio with changes in engine operating conditions.

Lean and Rich Air-Fuel Mixture

A ***lean air-fuel mixture*** contains a large amount of air compared to fuel. Look at **Figure 20-8A.** For gasoline, 20:1 is a very lean mixture.

A ***rich air-fuel mixture*** is the opposite of a lean mixture; more fuel is mixed with the air. For gasoline, 8:1 (8 parts air to one part fuel) is a very rich fuel mixture. Refer to **Figure 20-8B.**

A slightly lean mixture is desirable for high gas mileage and low exhaust emissions. Extra air in the cylinder ensures that all the fuel is burned. Too lean a mixture, however, can cause poor engine performance (lack of power, missing, and even engine damage).

A slightly rich mixture tends to increase engine power. However, it also increases fuel consumption and exhaust emissions. An over-rich mixture will reduce engine power, foul spark plugs, and cause incomplete burning (black smoke at engine exhaust).

Abnormal Combustion

Abnormal combustion occurs when the flame does not spread evenly and smoothly through the combustion chamber. The lean air-fuel mixtures, high operating temperatures, and low-octane fuels of today make abnormal combustion a problem.

Detonation

Detonation results when part of the unburned air-fuel mixture explodes violently. This is the most severe and engine-damaging type of abnormal combustion.

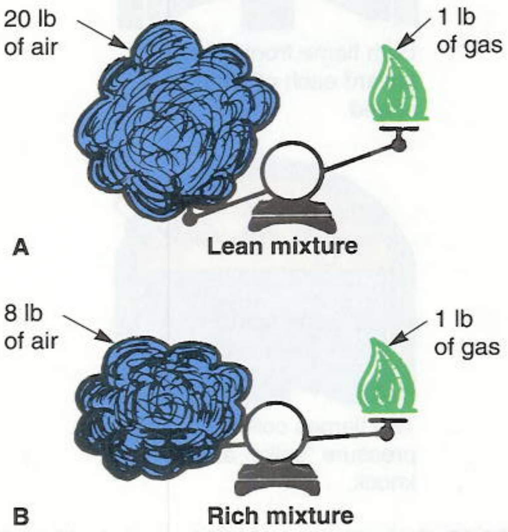

Figure 20-8. A—Lean fuel mixture has less fuel mixed with the air. B—Rich fuel mixture has more fuel mixed into the air.

Engine knock is a symptom of detonation. The combustion chamber pressure rises so quickly that parts of the engine vibrate. Detonation sounds like a hammer hitting the side of the engine. **Figure 20-9** shows what happens during detonation. Study the four phases.

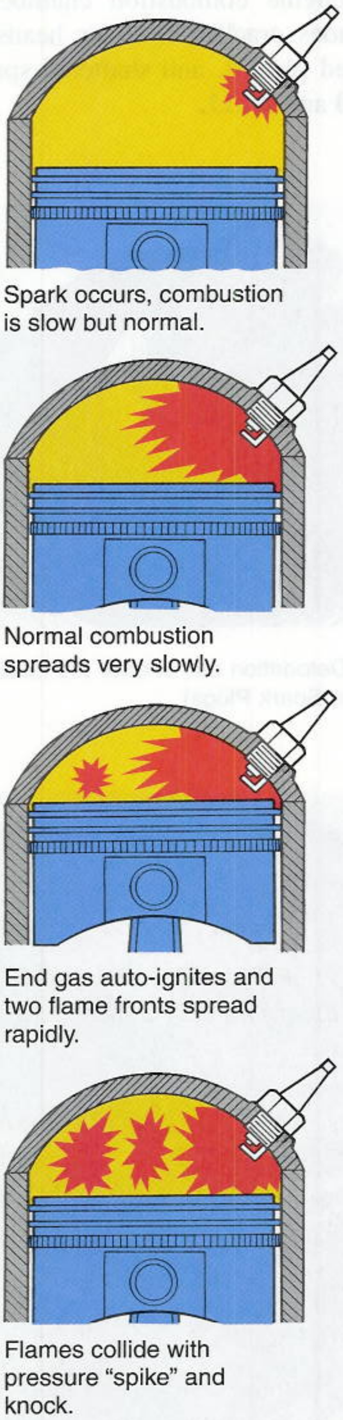

Figure 20-9. Detonation is caused by combustion being too slow. End gas, or unburned air-fuel mixture, ignites and two flame fronts collide with a loud knock.

A *ping,* or a mild knock, is a light tapping noise that can be heard during preignition. It is not as loud or as harmful as a detonation knock. Study **Figure 20-12.**

Preignition is similar to detonation, but the actions are reversed. Detonation begins *after* the start of normal combustion. Preignition begins *before* the start of normal combustion.

Caution!
Prolonged preignition can produce harmful detonation. If an engine pings or knocks excessively, serious engine damage can result. Correct the problem right away.

Dieseling

Dieseling, also called ***after-running*** or ***run-on***, is a problem in which the engine keeps running after the key is turned off. A knocking, coughing, or fluttering noise is heard as the fuel ignites and the crankshaft spins uncontrollably. When dieseling, the gasoline engine ignites the fuel from heat and pressure, somewhat like a diesel engine. With the ignition key off, the engine runs without voltage to the spark plugs.

The most common causes of dieseling are a high idle speed, carbon deposits in the combustion chambers, low-octane fuel, an overheated engine, or spark plugs that have too high a heat range. This problem will be discussed later in the text.

Spark Knock

Spark knock is an engine combustion problem caused by the spark plug firing too soon in relation to the position of the piston. Spark timing that is advanced too far causes combustion pressure to slam into the upward-moving piston. This causes maximum cylinder pressure before TDC, not just after TDC as it should.

Figure 20-13 shows what happens during spark knock. Spark knock can also lead to preignition and more damaging detonation.

Spark knock and preignition produce about the same symptoms—pinging under load. To find the cause of pinging, first check the ignition timing. If timing is correct, check other possible causes.

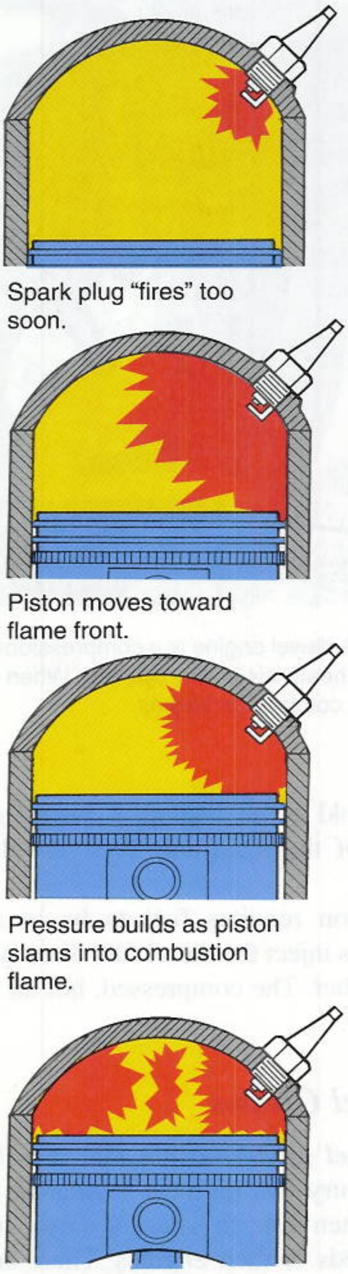

Figure 20-13. Spark knock is a ping or knock caused by an ignition timing problem.

Diesel Fuel

Diesel fuel is the second most popular type of automotive fuel. A gallon of diesel fuel contains more heat energy than a gallon of gasoline. It is a thicker fraction (part) of crude oil. Diesel fuel can produce more cylinder pressure and vehicle movement than an equal amount of gasoline. Diesel fuel now costs about the same as gasoline.

Since diesel fuel is thicker and has different burning characteristics than gasoline, a high-pressure injection system must be used to spray the fuel directly into the combustion chambers. A low-pressure injection system or carburetor would not meter the thick diesel fuel properly. Look at **Figure 20-14.**

Diesel fuel will not ***vaporize*** (change from a liquid to a gas) as easily as gasoline. If diesel fuel were to enter the

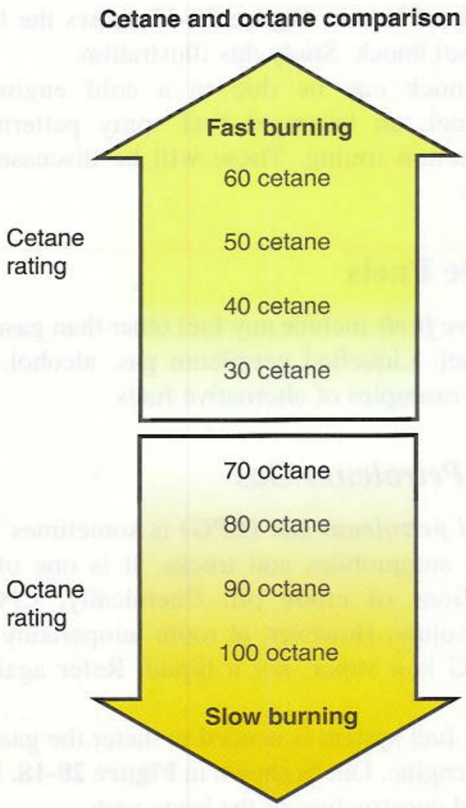

Figure 20-15. Diesel fuel cetane rating is the opposite of gasoline octane rating.

into the hot air, it begins to burn. **Figure 20-16** shows the phases of normal diesel combustion:

A— The piston moves up to compress and heat the air in the cylinder. Note that this is different than a gasoline engine, which compresses both fuel and air.

B— Diesel fuel is injected directly into the combustion chamber. The hot air makes the fuel begin to burn and expand.

C— More fuel is sprayed into the chamber. More pressure is developed and the piston begins to move down in the cylinder.

D— The rest of the fuel is injected into the chamber. Pressure continues to form, pushing the piston down on the power stroke.

Note that fuel is injected into the engine for several degrees of crankshaft rotation. This causes a smooth, steady buildup of pressure for quiet diesel engine operation.

Diesel Combustion Knock

When compared to gasoline engines, diesel engines knock almost all the time. The engine clatters and rattles as the diesel fuel ignites in the combustion chambers.

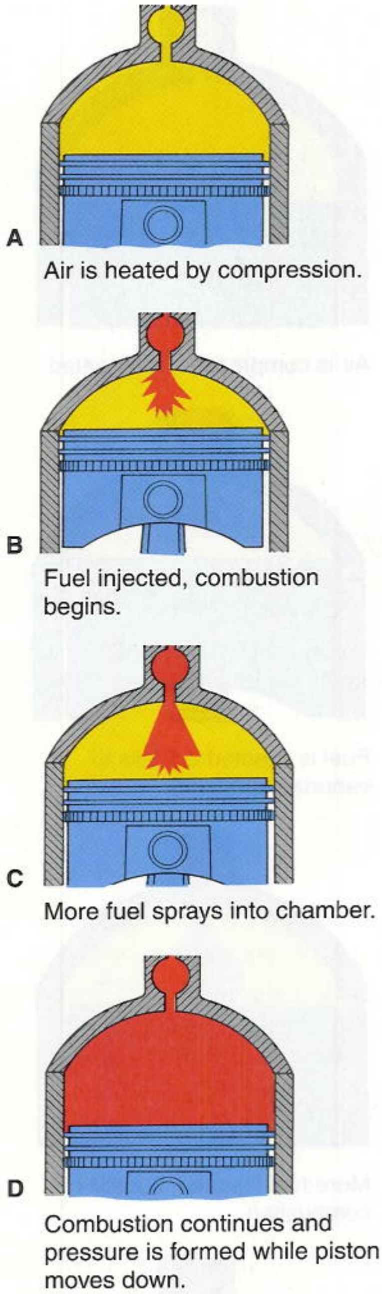

Figure 20-16. Normal diesel combustion.

Diesel knock occurs when too much fuel ignites at one time, producing a loud knocking noise. Excessive diesel knock can reduce engine power, fuel economy, and engine life.

Ignition lag is the time it takes diesel fuel to heat up, vaporize, and begin to burn. It is the time lapse between initial fuel injection and actual ignition (burning).

Ignition lag is a major controlling factor of diesel knock. If lag time is too long, a large amount of fuel can ignite, producing a louder-than-normal knock. A high cetane fuel, which has a short lag time, reduces the

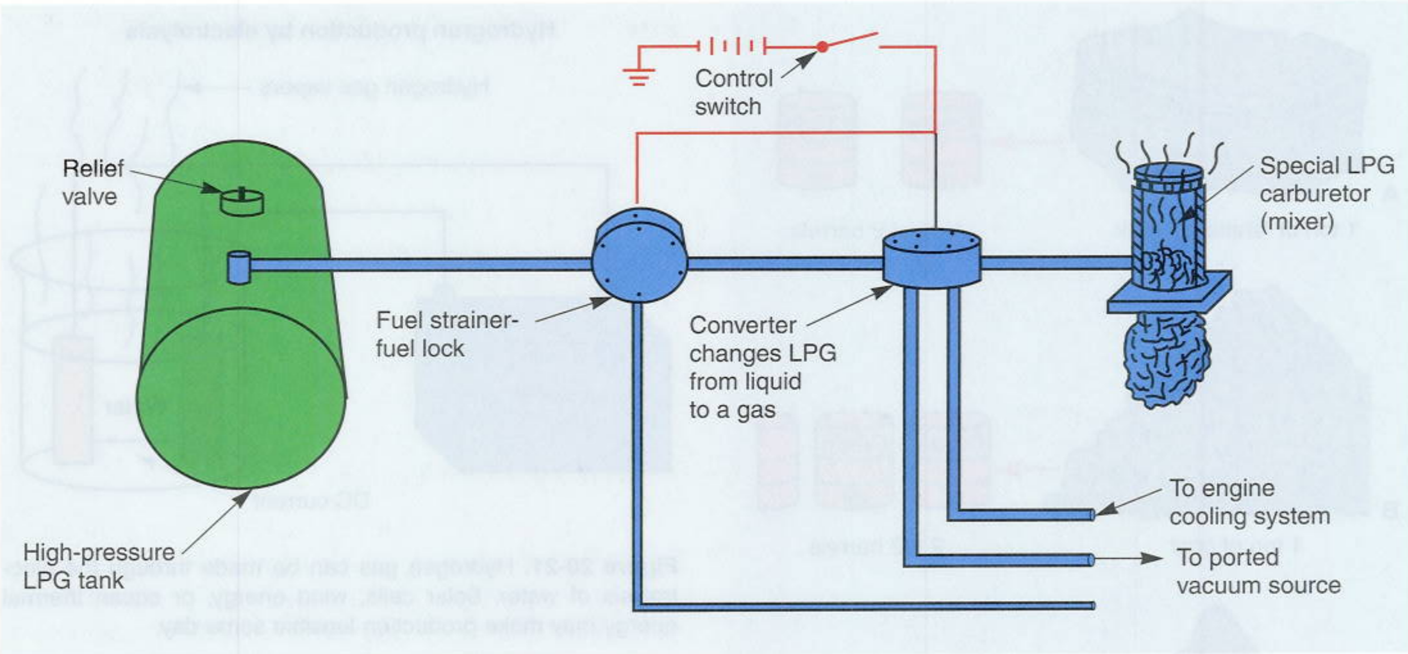

Figure 20-18. An LPG fuel system uses a high-pressure storage tank. A fuel strainer-fuel lock cleans fuel and prevents leakage when the engine is not running. A converter uses heat from the engine coolant to change the liquid LPG into a gas. A special carburetor meters LPG into the engine.

Tech Tip!

Methanol is commonly used as a racing fuel. It burns very hot but does not produce a visible flame. This can be very dangerous because you cannot see the flames if there is a fire. For increased safety, racing organizations have required the use of additives in methanol racing fuel to make its flame visible.

Gasohol

Gasohol, as the name implies, is a mixture of gasoline (usually 87 octane gasoline) and alcohol (usually grain alcohol). The mixture can range from 2–20% alcohol. In most cases, gasohol is a blend of 10% alcohol and 90% gasoline. See **Figure 20-19.**

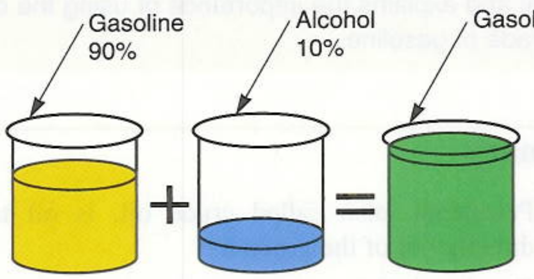

Figure 20-19. Gasohol is usually a mixture of 10% alcohol and 90% gasoline. (Ethyl Corp.)

Gasohol is commonly used as an alternative fuel in motor vehicles because fuel system and engine modifications are not needed. Many gas stations sell gasohol as a high-octane fuel. The alcohol tends to reduce the knocking tendencies of the gasoline. It acts like an anti-knock additive.

For example, 10% alcohol can increase 87 octane gasoline to 91 octane. Gasohol can be burned in a high-compression, high-horsepower engine without detonating and knocking.

Synthetic Fuels

Synthetic fuels are fuels made from coal, shale oil rock (rock filled with petroleum), and tar sand (sand filled with petroleum). See **Figure 20-20.**

Synthetic fuels are synthesized (changed) from a solid hydrocarbon state to a liquid or gaseous state. Synthetic fuels are being experimented with as a means of supplementing crude oil. As crude oil-based fuels become more expensive, synthetic fuels will become more practical.

Hydrogen

Hydrogen is a highly flammable gas that is a promising alternative fuel of the future. Hydrogen is one of the most abundant elements on our planet. It can be produced through the electrolysis of water (sending

- The octane rating of gasoline is a measurement of the fuel's ability to resist knocking or pinging.
- Normal gasoline combustion occurs when the spark plug ignites the fuel and burning progresses smoothly through the air-fuel mixture.
- A stoichiometric fuel mixture is a chemically correct, or perfect, air-fuel mixture.
- Detonation results when part of the unburned air-fuel mixture explodes violently.
- Preignition results when an overheated surface in the combustion chamber ignites the fuel mixture.
- Dieseling, also called after-running or run-on, occurs when the engine keeps running after the key is turned off.
- Diesel fuel is the second most popular type of automotive fuel.
- No. 2 diesel fuel is normally recommended for use in automotive diesel engines.
- A cetane rating indicates the cold starting ability of diesel fuel.
- Alternative fuels include any fuel other than gasoline and diesel fuel. LPG, alcohol, and hydrogen are examples of alternative fuels.

Important Terms

Fuel	Detonation
Combustion	Engine knock
Crude oil	End gas
Petroleum	Detonation damage
Hydrocarbons	Preignition
Exploration tests	Surface ignition
Refinery	Ping
Distillation	Dieseling
Fractionating tower	After-running
Gasoline	Run-on
Antiknock additives	Spark knock
Engine ping	Diesel fuel
Knock	Vaporize
Octane rating	Diesel fuel grades
Octane numbers	Viscosity
Octane enhancers	Paraffin
Oxygenates	Cloud point
Normal gasoline combustion	Water contamination
Stoichiometric fuel mixture	Water separators
Lean air-fuel mixture	Cetane rating
Rich air-fuel mixture	Compression ignition engine
Abnormal combustion	Diesel knock
Alternative fuels	Ignition lag
Liquefied petroleum gas (LPG)	Methyl alcohol
Alcohol	"Wood alcohol"
Ethyl alcohol	Methanol
Grain alcohol	Gasohol
Ethanol	Synthetic fuels
	Hydrogen

Review Questions—Chapter 20

Please do not write in this text. Place your answers on a separate sheet of paper.

1. _____, also called _____, is oil taken directly out of the ground.
2. What are hydrocarbons?
3. Crude oil is converted into more useful substances at a(n) _____.
4. _____ are extra chemicals added to gasoline to improve its operating characteristics.
5. The _____ of gasoline is a measurement of the fuel's ability to resist knock or ping.
6. If an automaker recommends gasoline with an octane number of 91, 87 octane gasoline is also acceptable. True or False?
7. Which of the following is *not* needed for proper combustion?
   (A) Air.
   (B) Compression.
   (C) Condensation.
   (D) Ignition.
8. Describe normal gasoline combustion.
9. Define the term "stoichiometric fuel mixture."
10. A(n) _____ air-fuel mixture ratio contains a large amount of air.
11. A(n) _____ air-fuel mixture ratio contains a large amount of fuel.
12. What are the results of lean and rich air-fuel mixtures?
13. Explain detonation, preignition, spark knock, and dieseling in a gasoline engine.
14. How does diesel fuel differ from gasoline?
15. Explain how ignition lag affects diesel combustion.
16. _____ is made from farm crops and _____ can be made out of wood chips, petroleum, garbage, and animal manure.
17. What is gasohol?