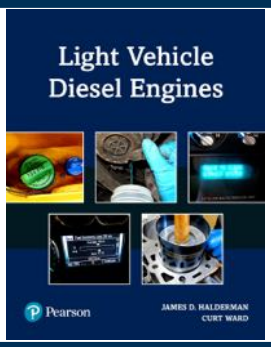
Light Vehicle Diesel Engines

First Edition



Chapter 1
Diesel Engine Operation

LEARNING OBJECTIVES (1 of 2)

1.1 Prepare for the light Vehicle Diesel engine (A9) ASE certification test content area “A” (general Diagnosis).

1.2. Explain how a four-stroke cycle engine operates.

1.3. List the various characteristics by which vehicle engines are classified.

LEARNING OBJECTIVES (2 of 2)

1.4 Discuss how a compression ratio is calculated.

1.5 Explain how engine size is determined.

1.6 Describe how displacement is affected by the bore and stroke of the engine.

ENGINES (1 of 2)

- **Purpose/Function of Engine**
  - Convert heat energy into mechanical energy
    - Mechanical energy
      - Propel vehicle
      - Power air-conditioning & power steering
      - Produce electrical power
    - Chemical energy in fuel is converted to heat energy
    - By burning fuel at controlled rate

Gas Engine On Engine Dynamometer

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ENGINES (2 of 2)

- **Combustion**
  - Chemical energy converted to heat energy
  - By burning diesel fuel at a controlled rate
    - Convert diesel fuel energy into heat
    - Within a combustion chamber
    - Combustion occurs above piston
    - Called internal combustion engine

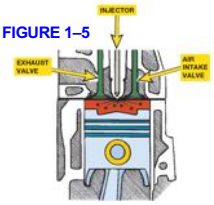

FIGURE 1–5

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FOUR-STROKE CYCLE OPERATION (1 of 1)

- **4-Stroke Cycle**
  - Developed by Nikolaus Otto
- **Stroke**
  - Movement of piston from TDC to BDC
  - Piston moves up and down, or
    - Reciprocates (moves up and down) in a cylinder
    - Piston is attached to crankshaft with connecting rod

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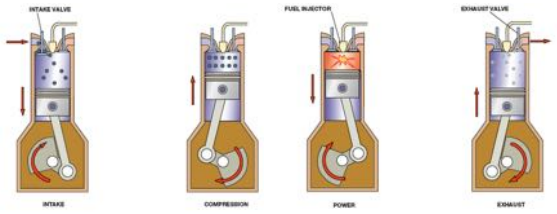
FIGURE 1–1 In diesel engine downward movement of piston draws air into cylinder through intake valve on intake stroke. On compression stroke, air is compressed by upward movement of piston with both valves closed. Fuel is injected and ignition occurs at beginning of power stroke, and combustion drives the piston downward to produce power. On exhaust stroke, upward-moving piston forces burned gases out open exhaust valve.



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QUESTION 1: ?

Which engine stroke brings in air?

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ANSWER 1:

Intake.

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ENGINE CONSTRUCTION OVERVIEW (1of 3)

- **BLOCK**
  - Solid frame, called an engine block
  - Constructed of cast iron or aluminum
  - Provides foundation for engine components & systems

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FIGURE 1–2 Cutaway of a diesel engine showing the cylinder, piston, connecting rod, and crankshaft.

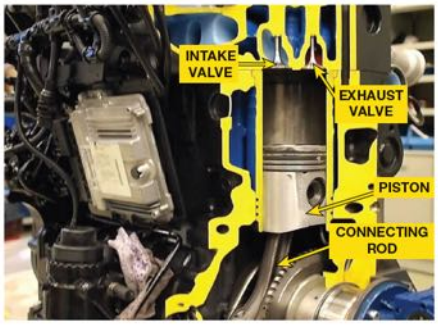

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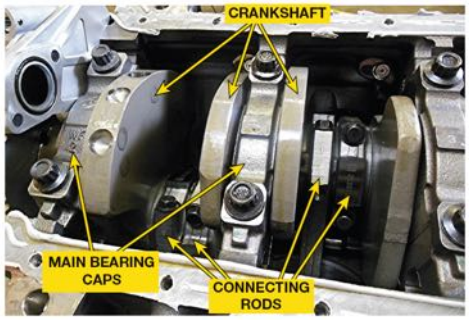
FIGURE 1–3 Rotating assembly for a V-8 engine that has 8 pistons and connecting rods, and one crankshaft.



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ENGINE CONSTRUCTION OVERVIEW (2 of 3)

- **ROTATING ASSEMBLY**
  - Pistons are installed in block
  - Move up and down during engine operation
  - Connected to connecting rods
  - Connect pistons to crankshaft
  - Crankshaft converts up/down piston motion
  - To rotary motion, transmitted to drive wheels

FIGURE 1–3

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FIGURE 1–4 A cylinder head with four valves per cylinder, two intake valves (larger) and two exhaust valves (smaller).

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ENGINE CONSTRUCTION OVERVIEW (3 of 3)

- **CYLINDER HEAD**
  - Seals top of cylinders in engine block
  - Contains both intake valve that allow air & and fuel in
  - Exhaust valves, which allow spent gases out
  - Constructed of cast iron or aluminum
  - Machined for valves

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DIESEL ENGINES (1 of 10)

- **Compression Ignition Engine**
  - Invented by Rudolf Diesel (1858–1913)
  - Uses heat created by compression to ignite fuel
  - Requires compression ratios of 16:1 & higher
  - Incoming air is compressed until the temperature
    - reaches about 1,000°F (540°C) heat of compression
  - Piston reaches TDC, fuel is injected into cylinder
  - Ignited by hot air
  - As fuel burns, it expands and produces power

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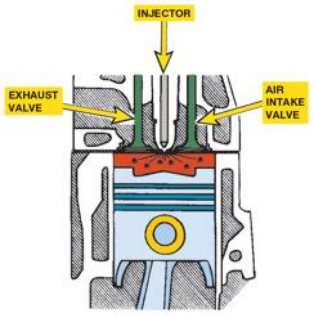
FIGURE 1–5 Diesel combustion occurs when fuel is injected into the hot, highly compressed air in the cylinder.



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DIESEL ENGINES (2 of 10)

- **Diesel Engine Advantages**
  - Compared to similar size gasoline engine:
    - **1. More torque output**
    - **2. Greater fuel economy**
    - **3. Long service life**

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DIESEL ENGINES (3 of 10)

- **Diesel Engine Disadvantages**
  - Compared to similar size gasoline-powered engine:
    - **1. Engine noise, especially when cold and/or idling**
    - **2. Exhaust smell**
    - **3. Hard starting in cold weather**
    - **4. Overall weight, heavier than a gasoline engine**
    - **5. Fuel availability**
    - **6. Extra cost compared to a gasoline engine**

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CHART 1-1 Comparison between a typical gasoline and a diesel engine.

SYSTEM OR COMPONENT	DIESEL ENGINE	GASOLINE ENGINE
Block	Cast iron and heavy	Cast iron or aluminum and as light as possible
Cylinder head	Cast iron or aluminum	Cast iron or aluminum
Compression ratio	17:1 to 22:1	8:1 to 12:1
Peak engine speed	2500 to 5000 RPM	5000 to 8000 RPM
Pistons	Aluminum with combustion pockets and heavy-duty connecting rods	Aluminum, usually flat top or with valve relief, but usually no combustion pockets except for engines with gasoline direct injection (GDI)

CHART 1-1

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DIESEL ENGINES (4 of 10)

- **Indirect Diesel Injection (IDI)**
  - Fuel injected into small pre-chamber
  - Connected to cylinder by narrow opening
  - Initial combustion takes place in pre-chamber
  - Slowing rate of combustion, reduces noise
  - Requires use of a glow plug for cold starts

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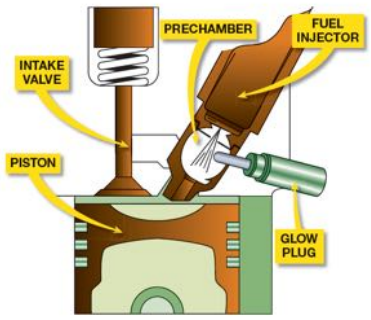
FIGURE 1–6 indirect injection IDI diesel engine uses a prechamber and a glow plug.



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DIESEL ENGINES (5 of 10)

- **Diesel Injection (DI)**
  - Fuel injected directly into cylinder
  - Piston has depression where initial combustion takes place
  - Generally more efficient than IDI engines
  - Tendency to produce greater amounts of noise

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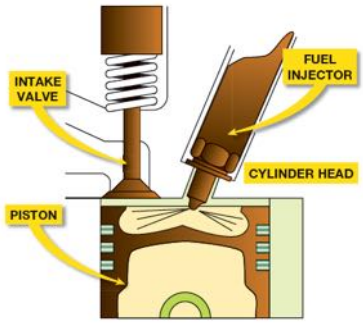
FIGURE 1–7 A direct injection diesel engine injects the fuel directly into the combustion chamber. Many designs do not use a glow plug.



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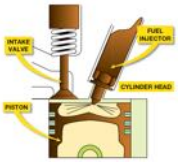
DIESEL ENGINES (6 of 10)

- **Fuel Injection**
  - Ignition occurs by injecting fuel into air charge
  - Heated by compression to about 1,000°F (538°C)
  - Chemical reaction of burning fuel creates heat
  - Causes gases to expand & piston to rotate crankshaft

FIGURE 1–7



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DIESEL ENGINES (7 of 10)

- **Three Phases of Combustion**
  - **Ignition Delay**
    - Near end of compression stroke, fuel injection begins, but ignition does not begin immediately, delayed
  - **Rapid Combustion**
    - Fuel first starts to burn, creating sudden rise in pressure
    - Sudden & rapid rise in combustion chamber pressure
    - Causes characteristic diesel engine knock
  - **Controlled Combustion**
    - Rest of fuel in combustion chamber begins to burn & injection continue
    - Process occurs near injector that contains fuel surrounded by air
    - Fuel burns as it mixes with air

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QUESTION 2: ?

Which phase of combustion causes a sudden and rapid rise in combustion chamber pressure, which causes the characteristic diesel engine knock?

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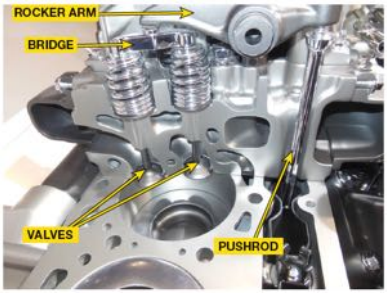
ANSWER 2:

Rapid Combustion

FIGURE 1–8 Cutaway of an overhead valve (OHV) V-8 engine showing the lifters,



DIESEL ENGINES (8 of 10)

- **Valve & Camshaft Arrangements**
  - intake & exhaust valves controlled by camshaft
  - Used to open valves
  - Older diesels uses 1 intake valve & 1 exhaust valve
  - Many newer engines use 2 intake & 2 exhaust valves

DIESEL ENGINES (9 of 10)

- **Overhead Valve (OHV) Engines**
  - Camshaft is located in block
    - Valves are operated by lifters, pushrods, &rocker arms.
  - Pushrod engine
    - Pushrods to transfer motion of camshaft lobes to valves
  - Cam-in-block design
    - Describe overhead valve or pushrod design
  - Overhead valve (OHV)
    - Overhead valve engine has camshaft in block, valves are in cylinder head

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DIESEL ENGINES (10 of 10)

- **Overhead Camshaft**
  - Camshaft in cylinder head
  - Called overhead camshaft-type
  - Single Overhead Camshaft (SOHC)
    - One overhead camshaft used
  - Double Overhead Camshaft (DOHC)
    - Two overhead camshafts are used,
    - One cam operating intake valve & other operating exhaust valves

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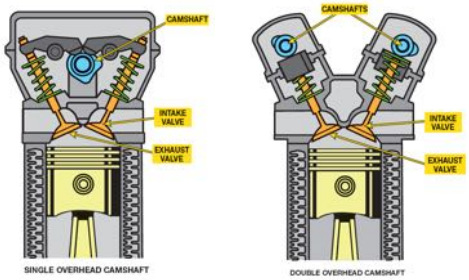
FIGURE 1–9 SOHC engines usually require additional components, such as a rocker arm, to operate all of the valves. DOHC engines often operate the valves directly.



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ENGINE SIZE (1 of 4)

- **BORE**
  - Diameter of cylinder
  - Measured in inches or millimeters (mm)
  - Larger the bore greater the piston head area
  - Pressure is measured in units, such as PSI
  - Greater area of piston head (square inches)
  - Higher force exerted by pistons to rotate crankshaft

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FIGURE 1–10 bore and stroke of pistons are used to calculate engine displacement.

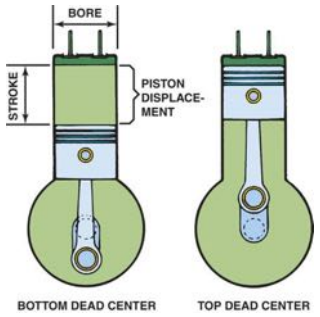

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FIGURE 1–11 crankshaft determines the stroke of the engine, which is the difference between the centerline of the crankshaft journal and the centerline of the connecting rod journal

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ENGINE SIZE (2 of 4)

- **STROKE**
  - Distance piston travels from TDC to BDC
  - Distance determined by throw of crankshaft
    - Throw is distance from centerline of crankshaft
    - To centerline of crankshaft rod journal
    - ½ the stroke

ENGINE SIZE (3 of 4)

- **NOTE: Changing connecting rod length does not change stroke of an engine. Changing connecting rod only changes position of piston in the cylinder. Only crankshaft determines stroke of an engine**

QUESTION 3: ?

Which is the definition of engine stroke?

ANSWER 3:

The distance the piston travels.

ENGINE SIZE (4 of 4)

- **Displacement**
  - Cubic inch (cu. in.) cubic centimeter (cc) volume displaced
  - How much air is moved by all of pistons
  - A liter (L) is equal to 1,000 cubic centimeters
  - Engines identified by their displacement in liters

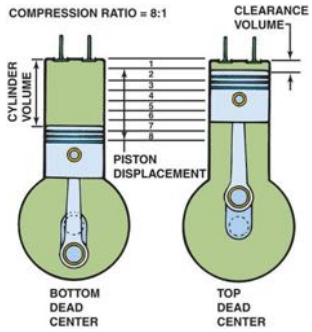
Cubic inch displacement = π R^2 X Stroke X Number of cylinders

COMPRESSION RATIO (1of 4)

- **Compression Ratio**
  - Ratio of difference in cylinder volume
    - When piston is at bottom of stroke to
    - Volume in cylinder above piston when piston is at TDC

$$\textit{Compression Ratio} = \frac{Volume\ BDC}{Volume\ TDC}$$

FIGURE 1–12 compression of an engine is expressed as a ratio of the volume, with the piston at the bottom of the cylinder, to that volume when the piston is at the top of cylinder.



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Think of a 2-Liter Bottle

TECH TIP

A two-liter bottle contains two liters of liquid. This is the volume of all four cylinders combined in a two-liter four-cylinder engine. A six-liter engine would therefore have the piston displacement of three two-liter bottles.

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TORQUE (1of 4)

- **Torque**
  - Rotating force that may or may not result in motion
    - Amount of force multiplied by length of lever
    - Through which it acts
    - Force of 10 pounds applied to end of 1 foot long wrench
    - To turn a bolt, a torque of 10 pound-feet (lb-ft) is achieved
    - Form of Work

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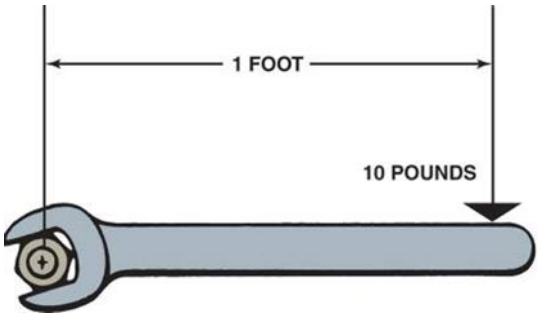
FIGURE 1–13 Torque is a twisting force equal to distance from pivot point times force applied, expressed in units called pound-feet (lb-ft) or newton-meters (N-m).



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Is torque ft-lb or lb-ft?

FREQUENTLY ASKED QUESTION

Definition of torque is a force (lb) applied to an object times the distance from that object (ft). Therefore, based on the definition of the term, torque should be:

- lb-ft (a force times a distance)
- Newton-meter (N-m) (force times distance)

However, torque is commonly labeled, even on some torque wrenches, as ft-lb.

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POWER (1 of 2)

- **Definition of Power**
  - Rate of doing work or torque
  - Horsepower & Altitude
    - Air density lower at high altitude
    - Power reduced at high altitude
    - One Horsepower =
      - Power to move 550 pounds one foot in one second,
      - Or 33,000 pounds one foot in one minute
      - (550 lb * 60 sec = 33,000 lb).

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POWER (2 of 2)

- **Horsepower Formula**
  - Horsepower is torque times RPM divided by 5252
  - Horsepower = Torque * RPM/ 5252.

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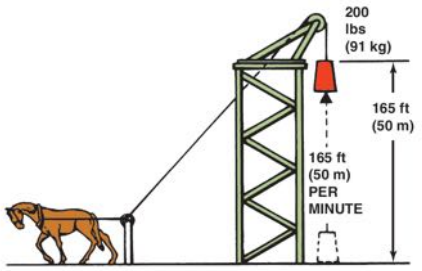
FIGURE 1–14 One horsepower is equal to 33,000 foot pounds (200 lbs X 165 feet) of



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How to Explain the Difference between Horsepower and Torque

TECH TIP

As Carroll Shelby, well-known race car driver and business owner said, "Horsepower sells cars, but torque wins races." Torque determines how fast the vehicle will accelerate, and horsepower determines how fast the vehicle will go..

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Summary (1 of 2)

- The four strokes of the four-stroke cycle are intake, compression, power, and exhaust.
- Gasoline engines draw an air-fuel mixture into the combustion chamber, but only air enters a diesel engine on the intake stroke.
- Engine size is called displacement and represents the volume displaced by all of the pistons.

Summary (2 of 2)

- There are three distinct phases or parts to the combustion in a diesel engine:
  - Ignition delay
  - Rapid combustion
  - Controlled combustion
- 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.