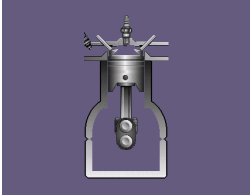Engine Repair

Engine Operation

Donald Jones
Brookhaven College

Engine Repair

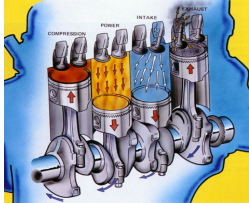## Basic Engine Operation

- The internal combustion process consists of:
  - admitting air and fuel into the cylinder
  - compressing the air and fuel mixture
  - igniting and burning the mixture
  - removing the burned gases from the cylinder

Engine Repair

Firing Order

- TDC - top dead center
- BDC - bottom dead center
- Mate cylinders
- Each cylinder's air/fuel mixture must be ignited just prior to TDC during the compression stroke
- What speed does the camshaft rotate at in relation to the crankshaft?
- How many rotations of the crankshaft are required to fire all the cylinders in a modern V8 engine?
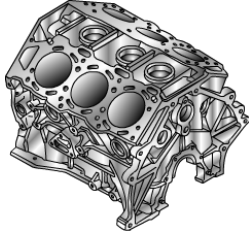

Engine Repair

Engine Design

- Engines are commonly referred to by the engine's displacement in cubic inches or liters
- An engine's displacement is the volume of each of its cylinders multiplied by the engine's number of cylinders
- Engines are commonly referred to by the number of cylinders and the cylinders arrangement

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Engine Repair

Common Cylinder Layouts

- Inline three cylinder
- Inline four cylinder
- Inline six cylinder
- opposed 4 cylinder
- 90 degree V6
- 60 degree V6
- 90 degree V8
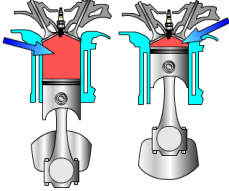- 90 degree V10

Engine Repair

Engine Displacement

- An engine's displacement is the volume of each of its cylinders multiplied by the engine's number of cylinders
- displacement = π (radius of the bore)^2 x stroke x number of cylinders
- calculate the displacement of a V6 engine with a 3.81" bore and a 3.39" stroke
  - 3.142 x (.5 x 3.81)^2 x 3.39 x 6
  - 232 cubic inches or 3.8 liters
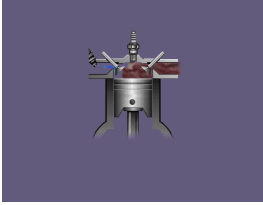
Engine Repair

Compression Ratio

- The compression ratio is the difference in cylinder volume between BDC and TDC
- Higher compression ratios improve engine performance and fuel economy

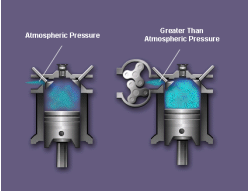### Engine Repair

Valve Overlap

- Both the intake and exhaust valves are open
- Occurs near TDC on exhaust stroke
- Incoming air charge aids in purging the exhaust gasses from the cylinder
- Measured in degrees of crankshaft rotation
- Excessive overlap degrades low speed engine performance

Engine Repair

Volumetric Efficiency

- The difference between how much air/fuel mixture enters an engine and the volume of the cylinder at BDC
- Varies at engine RPM
- Greatly affected by engine design

Atmospheric Pressure   Greater Than Atmospheric Pressure

Engine Repair

Overhead Valves - OHV

- Valves located in the cylinder head
- Camshaft located in block
- Push rods and lifters are used to transfer cam lobe motion to the rocker arms
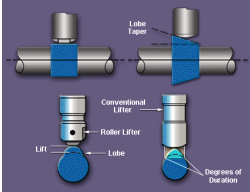
Engine Repair

Overhead Cam - OHC

- Camshaft located in cylinder head
- Camshaft may operate the valves directly or use rocker arms
- SOHC use one camshaft for intake and exhaust valves
- DOHC engines use separate camshafts for the intake and exhaust valves
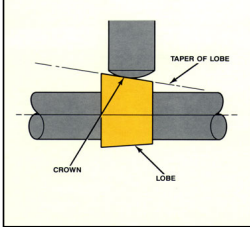
Engine Repair

Camshaft

- Controls valve operation
  - Lift - how far the valve opens
  - Duration - how long the valve remains open
- Rotates at one half crankshaft speed

Lobe Taper
Conventional Lifter
Roller Lifter
Lift
Lobe
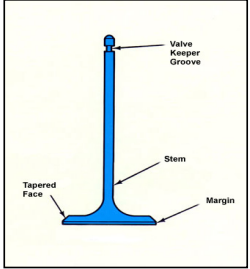Degrees of Duration

Lifter Rotation

Engine Repair

- The lifter contacts the cam lobe slightly off center to the lobe's centerline
- The cam lobe is ground at an angle
- The lifter base is convex
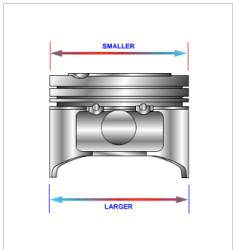- This causes the lifter to rotate and extends component life

Poppet Valves

Engine Repair

- Valve parts
  - keeper groove
  - stem
  - head
  - face
  - margin
- Multiple valves per cylinder cylinder are used to reduce valve weight and increase volumetric efficiency
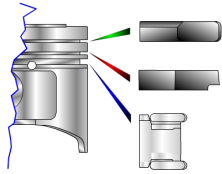

Pistons

Engine Repair

- Aluminum construction with steel struts or inserts to limit piston expansion
- Two types of pistons
  - full skirt
  - slipper skirt
- Wrist pin bore
- Ring grooves or ring lands
- Piston notch points toward timing chain or belt to aid in engine assembly
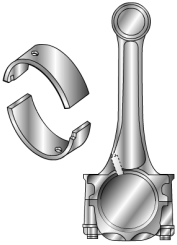

Piston Rings

Engine Repair

- Rings seal combustion chamber, remove excess oil from cylinder walls and transfer heat from piston to block
- Rings are commonly made of cast iron with coatings such as graphite, phosphate, molybdenum or chromium
- Oil control rings may be segmented or cast iron style
- Ring end gap allows for expansion of the rings due to heat
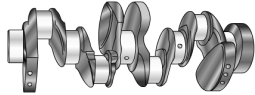

Connecting Rods

Engine Repair

- Rods are commonly made of forged steel and utilize an I beam design for maximum strength and minimum size
- Piston pin floats in rod and/or piston
- The rod assembly may contain lubrication passages
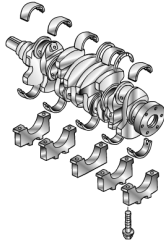

Crankshaft

Engine Repair

- Constructed of cast iron, forged cast steel or nodular iron
- Journals
  - rod
  - main
- V type engines have fewer journals
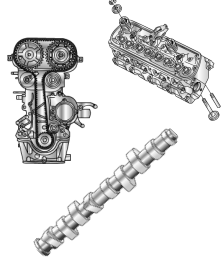- Counterweights

Engine Repair

Bearings

- Tri-metal insert bearings
  - steel backing
  - copper layer
  - babbit surface
- Two piece bearings have about .001" of crush when installed
- One piece bearings are a press fit have no crush factor
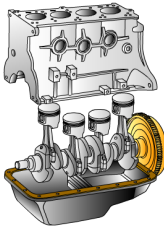
Engine Repair

Engine Component Jeopardy

- Bolts to the top of the block and contains the valves
- Open and close to admit fuel/air mixture and release exhaust gasses
- Uses egg shaped lobes to open the valves
- Closes the valves
- Used to drive the camshaft at one half crankshaft speed
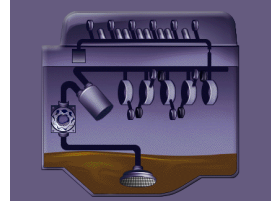
Engine Repair

Engine Component Jeopardy

- Contains the pistons and crankshaft
- Moves up and down in the cylinder and compresses the air fuel mixture
- Connects the piston to the crankshaft
- Converts reciprocal motion of the piston and connecting rod into rotary motion

Engine Repair

Lubrication System Components

- Engine Oil
- Oil Reservoir
- Oil Pickup
- Oil Pump
- Oil Filter
- Oil Passages
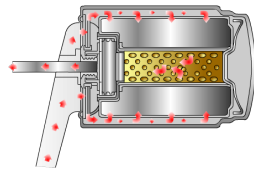
Engine Repair

Oil Pumps

- Deliver pressurized oil to the oil filter
- Three types of oil pumps are commonly used in automotive engines
  - gear
  - rotor
  - gerotor
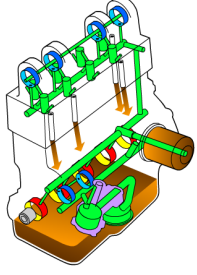
Engine Repair

Oil Filter

- Full Flow Oil Filter
  - all of the pump output flows through the filter
- Anti-drainback Valve
  - keeps oil filter and lubrication passages primed when engine is off
- Bypass Valve
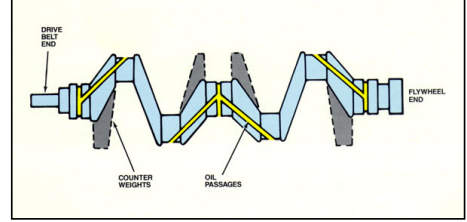 - allows oil to bypass filter element when the filter element is blocked

Engine Repair

Lubrication System Operation

- Oil from the pan travels through the pickup tube to the oil pump
- Pump output is routed through the filter and to oil passages in the block cylinder head
- Oil passages are also present in the crankshaft and other engine components
- Moving engine components such as the pistons, crankshaft and camshaft, ride on a film of oil

Engine Repair

Crankshaft Oil Passages

DRIVE BELT END

FLYWHEEL END

COUNTER WEIGHTS

OIL PASSAGES

Engine Repair
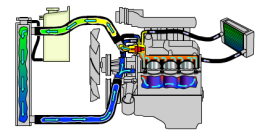
Engine Oil Ratings

- Oil Performance
  - API - American Petroleum Institute
  - SN is currently recommended for today's vehicles
- Viscosity Grade
  - SAE - Society of Automotive Engineers
  - W - winter
- Energy Conservation Rating

AMERICAN PETROLEUM INSTITUTE
FOR GASOLINE ENGINES
CERTIFIED

SAE 5W-30
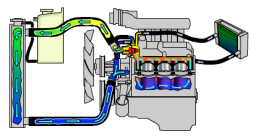MOTOR OIL
1 QUART (0.946L)

Engine Repair

Cooling System

- Maintain an optimum operating temperature under all conditions
- Efficiently remove excess heat
- Bring engine to normal operating temperature a soon as possible

Engine Repair

Cooling System Operation

- Coolant flow:
  - radiator
  - lower radiator hose
  - coolant pump
  - engine block coolant passages
  - cylinder head coolant passages
  - thermostat
  - upper radiator hose

Engine Repair

Engine Coolant

- A 50/50 mix of coolant and water provides optimum performance
- Raises boiling point and lowers the freezing point
- The cooling system is pressurized to further increase the coolant's boiling point
- Protects cooling system components from rust and corrosion

50% water

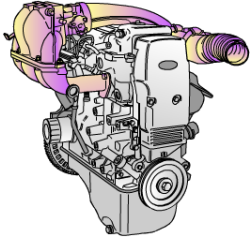50% coolant

Engine Repair

Engine Coolant Types

- The standard green coolant and orange coolant are both ethylene glycol based
  - green – silicate corrosion inhibitors
  - orange – organic acid corrosion inhibitors
- Do not mix or interchange coolant types

Engine Repair
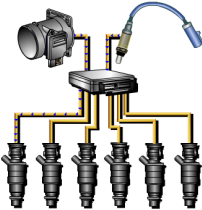
Intake & Exhaust Manifolds

- Intake Manifolds
  - runners should be equal in length
  - long runners improve low speed performance
  - short runners improve high speed performance
- Exhaust Manifolds
  - equal length runners promote exhaust scavenging

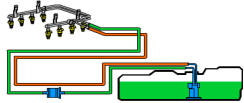Engine Repair

Engine Control Systems

- The Powertrain Control Module (PCM) monitors engine and vehicle operating conditions with sensors and controls powertrain systems
  - fuel and air
  - ignition
  - emission
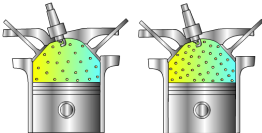 - transmission

Engine Repair

Fuel System

- Fuel Tank
- Fuel Pump
- Fuel Lines
- Fuel Rail
- Fuel Pressure Regulator
- Fuel Injectors

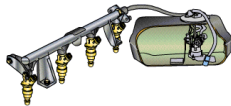Engine Repair

Air Fuel Ratios

- Ideal
  - 14.7 to 1
- Lean
  - 15 to 1 or greater
  - increased fuel economy
- Rich
  - 14 to 1 or less
  - reduced fuel economy

Engine Repair

Fuel Injectors

- Fuel injectors are turned on by the PCM
- A longer on-time provides a richer mixture
- The on time is referred to as pulse width and is measured in milliseconds
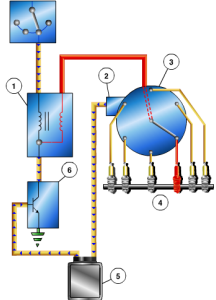
Engine Repair

Ignition System

- Provides sufficient spark at the correct time to ignite the air fuel mixture
- Most of today's vehicles use distributorless ignition with computer controlled spark advance systems
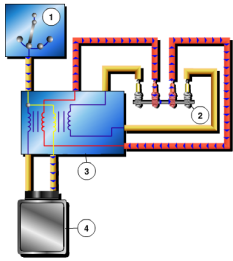

Engine Repair

Ignition Operation

1. Ignition coil
2. Camshaft position sensor
3. Distributor
4. Spark plugs
5. Powertrain control module
6. Ignition module

Engine Repair

Distributor-less Ignition

1. Ignition switch
2. Spark plugs
3. Coil pack
4. Powertrain control module

Engine Repair

Vehicle Emissions

- HC - hydrocarbons
  - fuel not burned during combustion
  - increases with misfires
- CO - carbon monoxide
  - a by product of incomplete combustion
  - increases with rich mixtures
- NOX - oxides of nitrogen
  - formed by heat and pressures in the combustion chambers
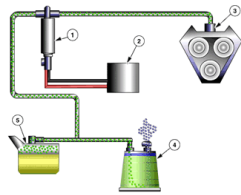 - increases with lean mixtures

Engine Repair

Evaporative Emissions

- The evaporative emission systems stores evaporative HC emissions when the vehicle is not being operated
  1. Purge valve
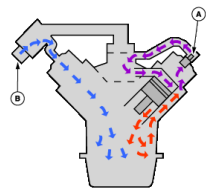 2. PCM
  3. Intake
  4. Charcoal canister
  5. Fuel Tank

Engine Repair

PCV System

- The Positive Crankcase Ventilation (PCV) System recycles crankcase gases back through the engine where they are burned reducing HC and CO emissions
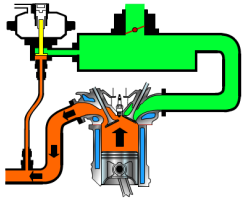 A. PCV Valve
  B. Filtered Air inlet

Engine Repair

EGR System

- The Exhaust Gas Recirculation (EGR) System is designed to reintroduce exhaust gas into the combustion cycle lowering combustion temperatures and reducing the formation of NOX
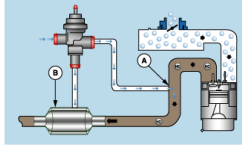
Engine Repair

Secondary AIR

- Air is injected into the exhaust stream to continue the burning process and reduce HC and CO emissions
  A. Air is delivered upstream during warm-up
  B. Air is delivered downstream after warm-up

Engine Repair

Catalytic Converters

- Conventional Oxidation Catalysts are used to reduce HC and CO
- Three-Way Catalysts are used to reduce HC, CO and NOX

1. HC, CO and NOX
2. NOX - O2 => N2 + H2O
3. HC + O2 => CO2 + H2O
4. CO + O2 => CO2