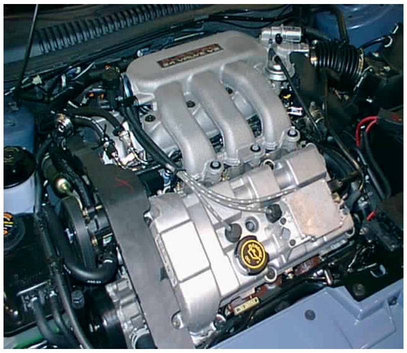
# Engine Operation

Matthew Whitten
Brookhaven College

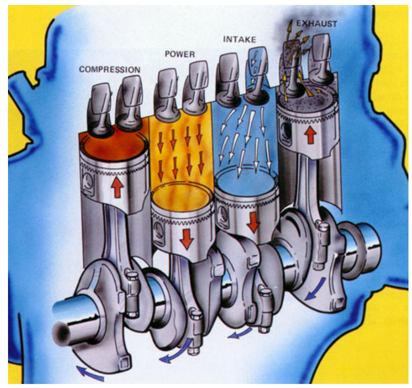
## Engine Operation

- Engine Design and Operation
- Engine Components
- Lubrication and Cooling Systems
- Fuel, Ignition and Emission Control Systems



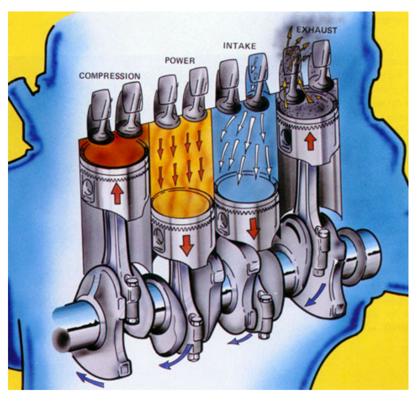
## Four Stroke Cycle

- Intake
  - intake valve open
- Compression
  - both valves closed
- Power
  - both valves closed
- Exhaust
  - exhaust valve open



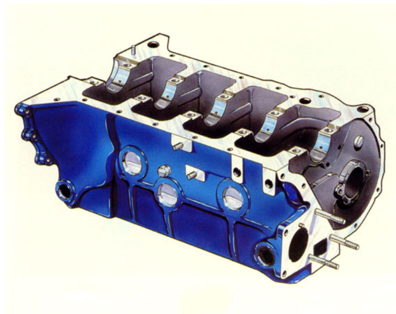

## Firing Order & Mate Cylinders

- An engine's firing order refers to the order in which the cylinder's power strokes occur
  - 1 - 3 - 4 - 2
- An engine's mate cylinders are always in the same physical position, but on the opposite stroke
  - 1 and 4
  - 3 and 2



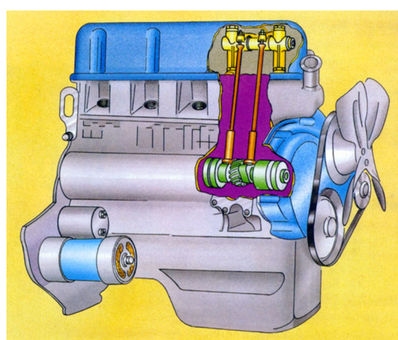
## Common Cylinder Layouts

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



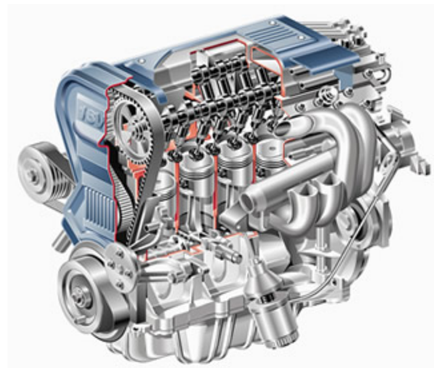
## Overhead Valves - OHV

- 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



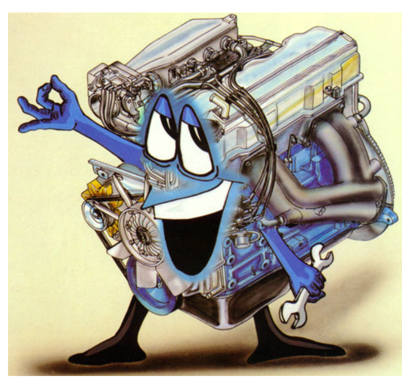
## Overhead Cam - OHC

- Camshaft located in cylinder head
- Camshaft may operate the valves directly or use rocker arms
- Some engines use separate camshafts for the intake and exhaust valves - DOHC



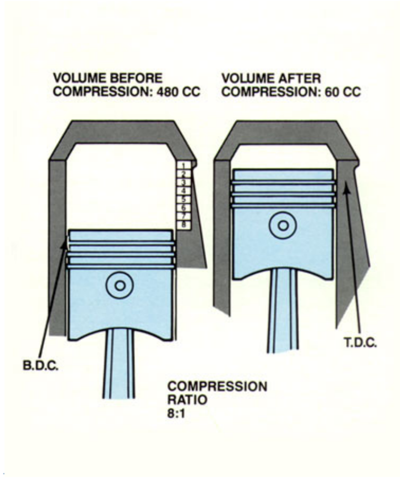
## Engine Displacement

- 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
- displacement = $\pi$ (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



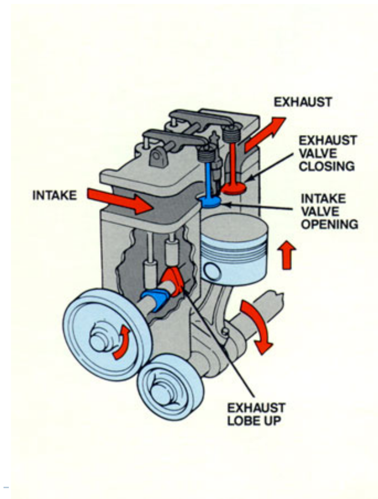
## Compression Ratio

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




## 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

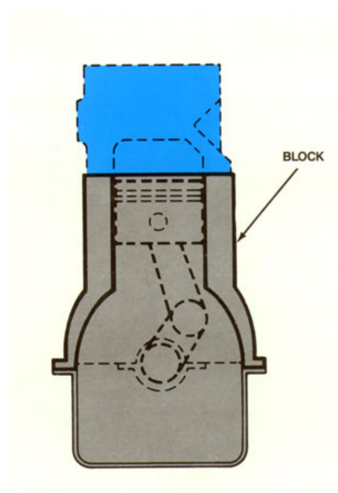


## Volumetric Efficiency

- 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

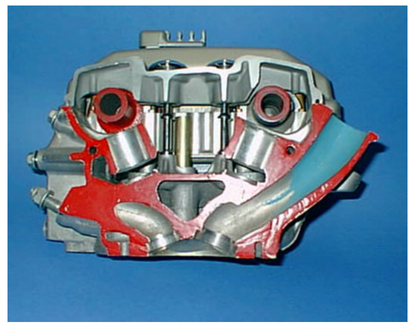
## Cylinder Block

- One piece casting
- Cylinder bores
- Cylinder head mating surface
- Bearing bores
- Cooling jacket
- Lubrication system passages

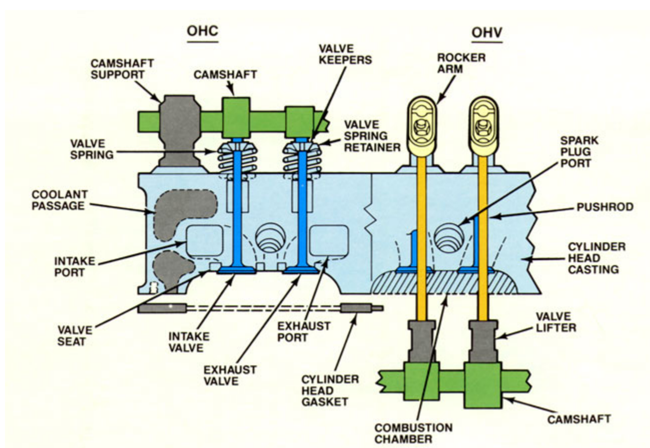


## Cylinder Head

- Cast iron or aluminum construction includes
  - Valve seats
  - Valve guides
  - Spark plugs
  - Cooling jacket
  - Lubrication Passages
- Combustion chamber shape is used to control combustion process



## OHC and OHV Components

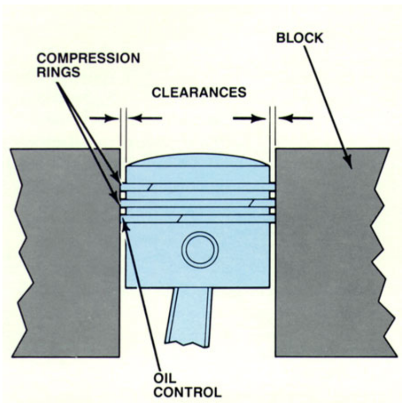


## Pistons

- 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
- Most pistons have notch that points toward timing chain or belt to aid in engine assembly

## Piston Rings

- Ring functions
  - seal combustion chamber
  - remove excess oil from cylinder walls
  - cool pistons
- 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



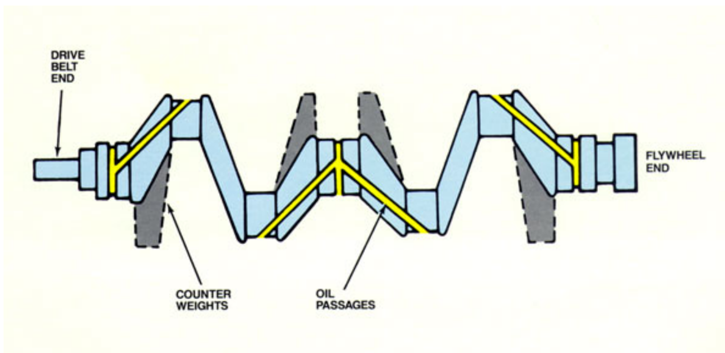
## Connecting Rods

- 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
- Rod cap alignment and torque is crucial

## Crankshaft

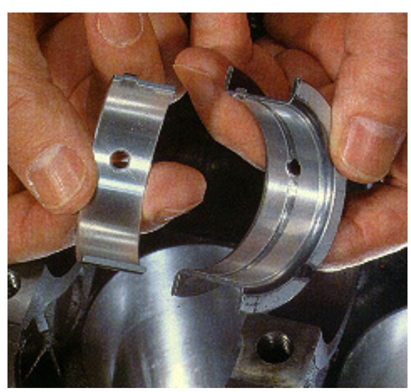
- Converts reciprocal motion into rotary motion
- Construction
  - cast iron, forged cast steel or nodular iron
  - journals
    - rod
    - main
    - V type engines have fewer journals
  - counterweights
  - lubrication passages

## Crankshaft Oil Passages

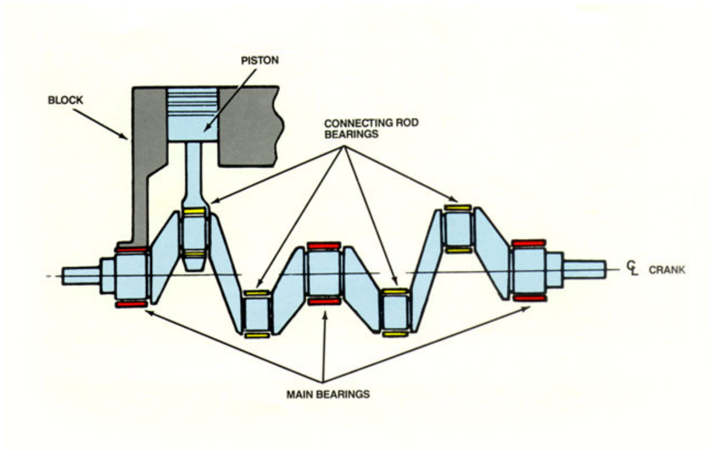



## Bearings

- 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

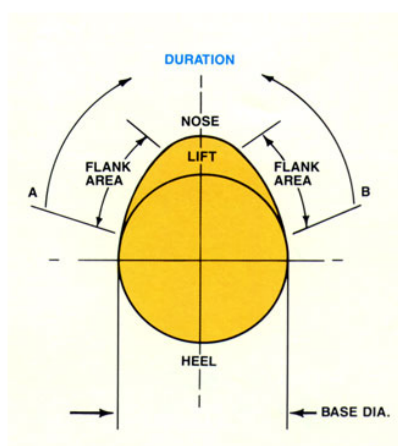


## Crankshaft Bearings




## Camshaft

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

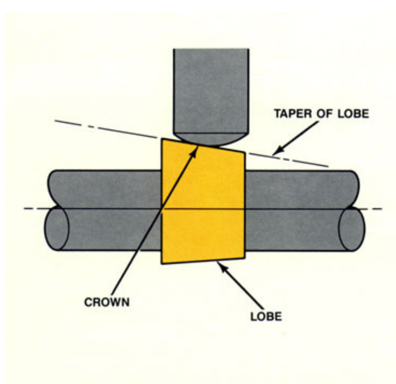


## Lifters

- Transform rotating cam lobe motion into up and down motion
- Roller lifters are used to reduce friction and wear
- Some OHC engines do not use lifters

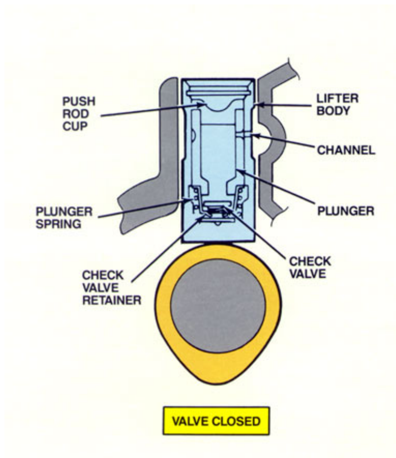
## Lifter Rotation

- 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



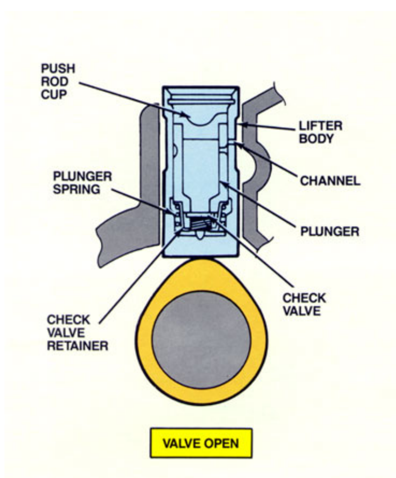
## Lifter Operation - Valve Closed

- The plunger spring forces the plunger up and aligns the oil channel passage
- The check valve is open
- Oil is free to enter or exit the lifter body and accommodate any changes in valve train tolerances



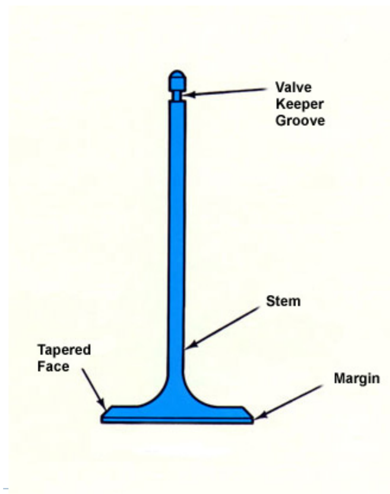

## Lifter Operation - Valve Open

- As the intake or exhaust valve begins to open the plunger moves down closing the oil channel passage
- The check valve is closed
- The oil is trapped in the lifter body and the lifter acts like a solid piece of metal



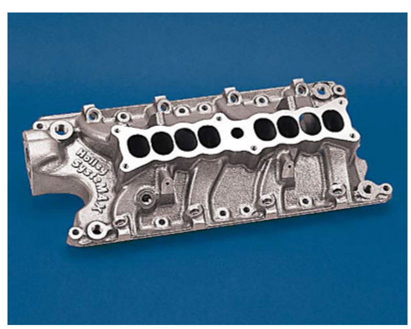
## Valves

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



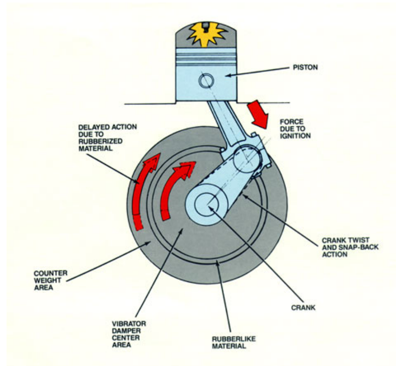

## Intake and Exhaust Manifolds

- 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



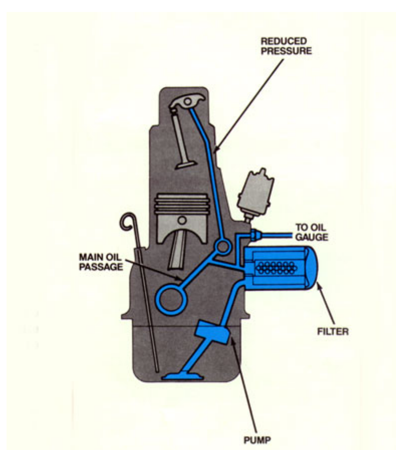
## Vibration Damper

- Two piece hub separated by a rubber section
- The inner hub turns with the crankshaft which accelerates and decelerates with each power stroke
- The outer hub remains slightly behind inner hub during power strokes due to rubber flexing
- The outer hub then catches up to the inner hub damping out the power stroke's vibration




## Lubrication System

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

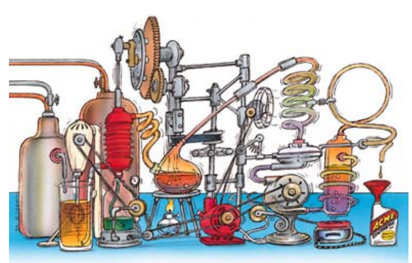


## Engine Oil Functions

- Lubrication
  - full film lubrication
  - boundary lubrication
- Sealing
  - rings to cylinder walls
- Cooling
  - carries away engine heat
- Cleaning
  - detergents and dispersants hold contaminants in suspension
- Corrosion Protection
  - corrosion inhibitors coat metal components


## Oil Composition

- 80% base lubrication stock
- 20% additives
  - anti-wear additives
  - detergent/dispersant
  - oxidation inhibitors
  - rust and corrosion inhibitors
  - viscosity index improvers
  - foam inhibitors
  - pour point depressants
  - friction modifiers

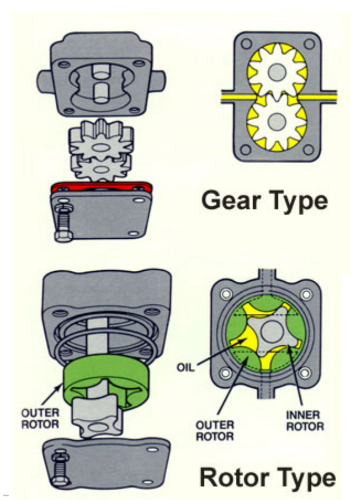


# Oil Ratings

- Oil Performance
  - API - American Petroleum Institute
  - SJ is currently recommended for today's vehicles
- Viscosity Grade
  - SAE - Society of Automotive Engineers
  - W - winter
- Energy Conservation Rating
  - I - improves fuel economy 1.8%
  - II - improves fuel economy 2.7%

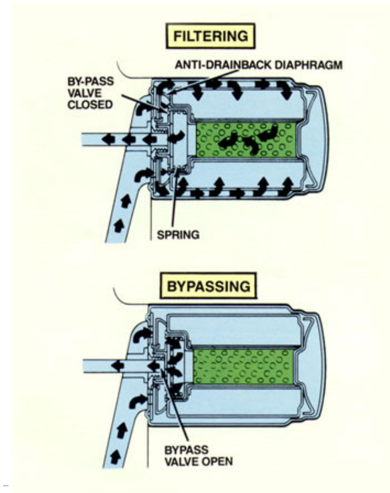
# Oil Pumps

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

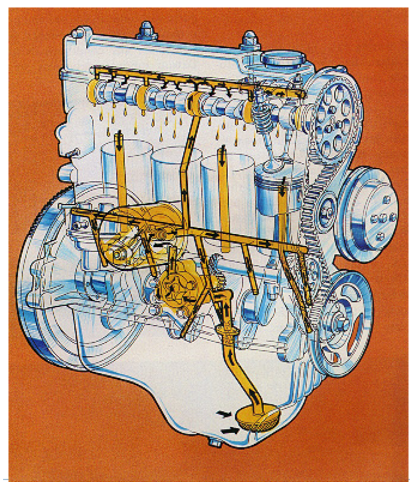


## Oil Filter

- 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



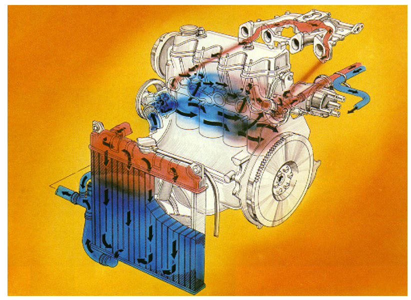

## Lubrication System Operation



- Pickup Tube Screen
- Oil Pickup Tube
- Oil Pump
- Oil Filter
- Oil Galleys
- Crankshaft
- Cylinder Walls
- Lifters
- Push rods
- Camshaft
- Rocker Arms
- Valve Stems and Guides

## Cooling System

- maintain an optimum operating temperature under all conditions
- efficiently remove excess heat
- bring engine to normal operating temperature a soon as possible

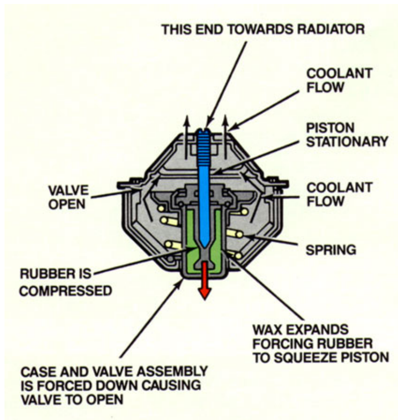


## Engine Coolant

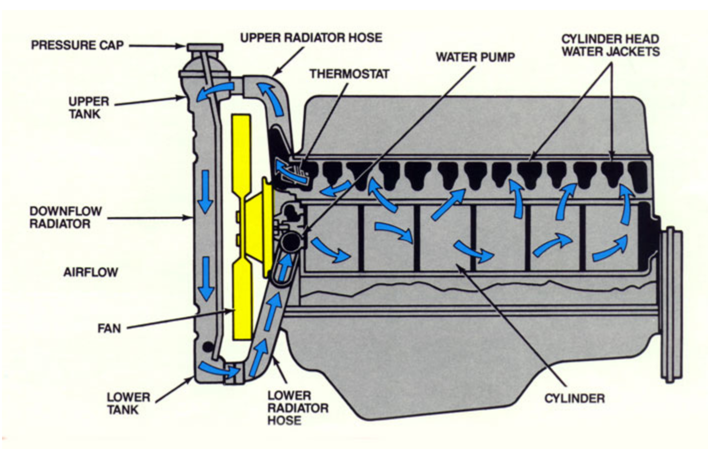
- the coolant carries away about 33% of the engines heat
- a 50/50 mix of coolant and water provides optimum performance
- raises boiling point and lowers the freezing point
- the cooling system is pressurized to further increase the coolant's boiling point
- protects cooling system components from rust and corrosion

# Thermostat

- Controls engine's minimum operating temperature
- Restricts coolant flow to radiator when cold and opens as the engine warms up
- Thermostats begin to open slightly before their rated temperature and are fully open several degrees after their rated temperature
- Even when fully open the thermostat continues to restricts coolant flow




# Cooling System Operation



## EEC System

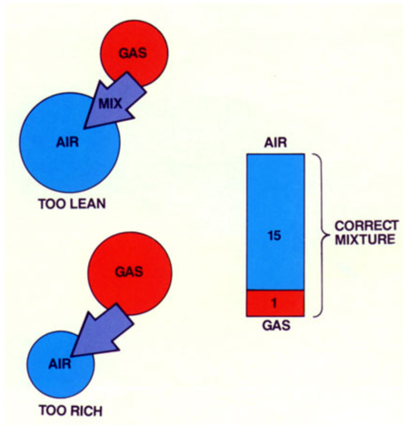
- Monitors engine and vehicle operating conditions with sensors
- Controls powertrain systems
  - fuel
  - ignition
  - emission
  - transmission

## EEC System Components

- Input Sensors
  - MAF - mass air flow
  - TP - throttle position
  - O2 - oxygen
  - ECT - engine coolant
  - IAT - intake air temperature
  - VSS - vehicle speed
  - CMP - camshaft position
  - CKP - crankshaft position
- Output Actuators
  - fuel pump relay
  - fuel injector solenoids
  - IAC - idle air control
  - EGR solenoid
  - ICM - ignition control module
  - lockup torque converter solenoid
  - transmission shift solenoids

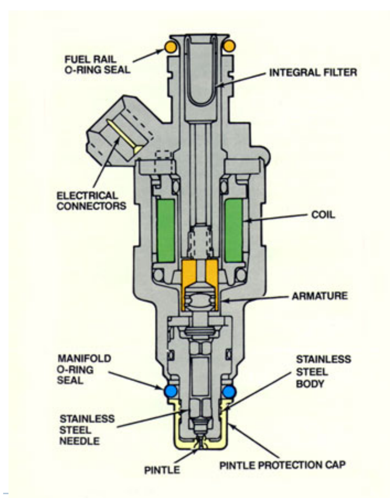
## Air Fuel Ratios

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



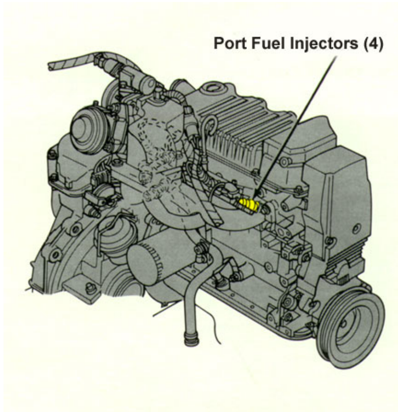

## Fuel Injector

- Fuel injectors are turned on by the PCM
- The PCM controls the fuel injector's ground path
- A longer on-time provides a richer mixture
- The on time is referred to as pulse width and is measured in milliseconds



## Types of Fuel Injection

- Throttle Body Injection
  - one or more fuel injectors located above the throttle plates
- Port Fuel injection
  - one fuel injector per cylinder located below the throttle plates near the intake valve
  - the injectors may be bank fired or sequentially fired

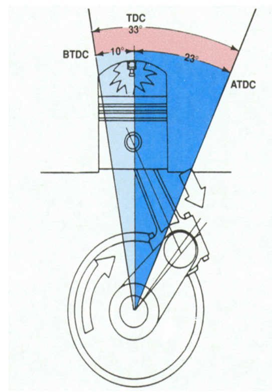



## Ignition System

- 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

## Ignition Timing

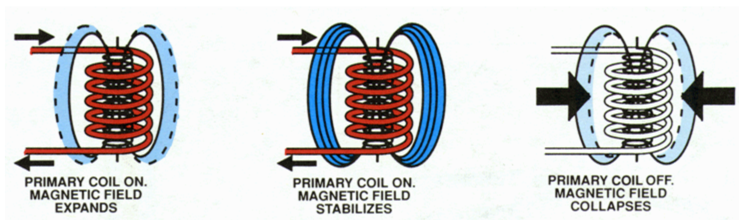
- ignition timing refers when the spark plugs fire in relation to the piston's position during the compression stroke
- for the engine to operate efficiently the combustion process should be completed approximately 23 degrees after top dead center




## Ignition Components

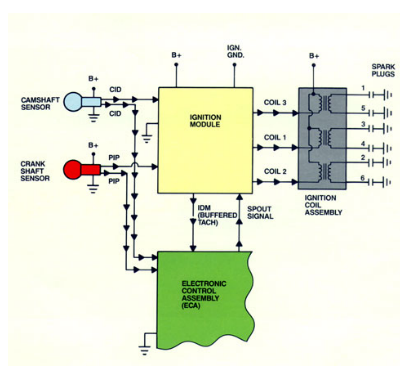
- Primary Circuit Components
  - battery
  - ignition switch
  - primary wiring
  - camshaft position sensor
  - ignition module
  - coil
- Secondary Circuit Components
  - coil
  - cap and rotor
  - secondary wiring
  - spark plugs

## Coil Operation



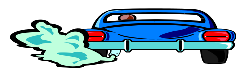

## Ignition System Signals

- PIP - profile ignition pickup signal
  - provides crankshaft speed and position from CKP
- CID - cylinder identification signal
  - provides verification that the ICM fired the coil successfully
- SPOUT- spark output signal
  - provides ignition spark timing signal from PCM
- IDM - ignition diagnostic monitor signal
  - provides verification that the ICM fired the coil successfully



## Controlled 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

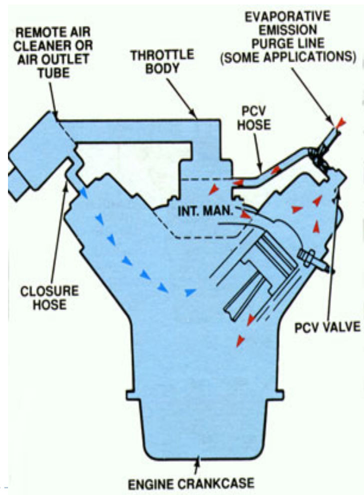


## Emission Control Systems

- PCV
  - controls HC and CO blow-by
- EGR
  - reduces oxides of nitrogen
- EVAP
  - controls HC
- Catalytic Converter
  - reduces HC, CO and oxides of nitrogen (TWC)
- Secondary Air System
  - reduces HC and CO

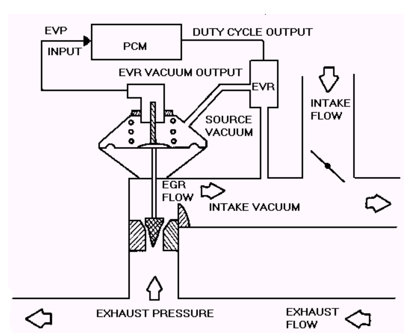
## PCV System

- the Positive Crankcase Ventilation (PCV) System recycles crankcase gases back through the engine where they are burned
- the PCV valve regulates the amount of ventilating air and blow-by gas to the intake manifold and prevents backfire from traveling into the crankcase



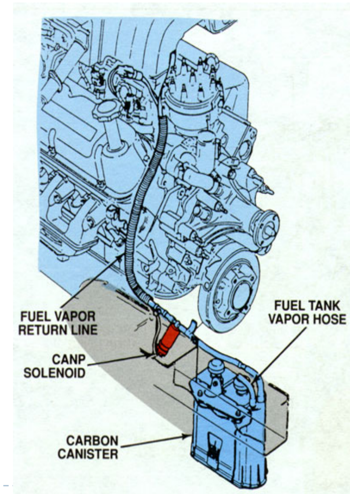

## EGR System

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



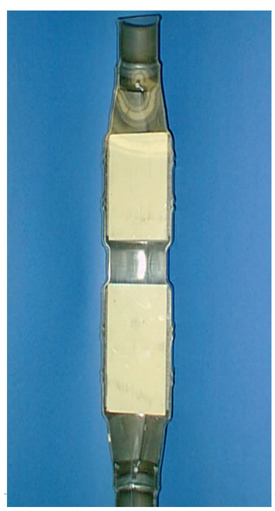
## EVAP System

- fuel vapors trapped in the sealed fuel tank are vented through the fuel vapor separator valve in the top of the tank to be stored in the carbon canister until they are purged to the engine for burning




## Catalytic Converters

- the Oxidation Catalytic Converter is used to reduce HC and CO
- the Three-Way Catalytic Converter is used to reduce HC, CO and $NO_X$



## Secondary Air System

- the secondary air system is utilized to reduce HC and CO emissions by continuing the combustion process in the exhaust manifold and the catalytic converter