ME 165
Mechanical Engineering Fundamentals

Lecture 5

Md. Aminul Islam
Lecturer
Department of Mechanical Engineering, BUET

IC Engine Subsystems

Engine Subsystems

https://www.youtube.com/watch?v=ZQvfHyfgBtA

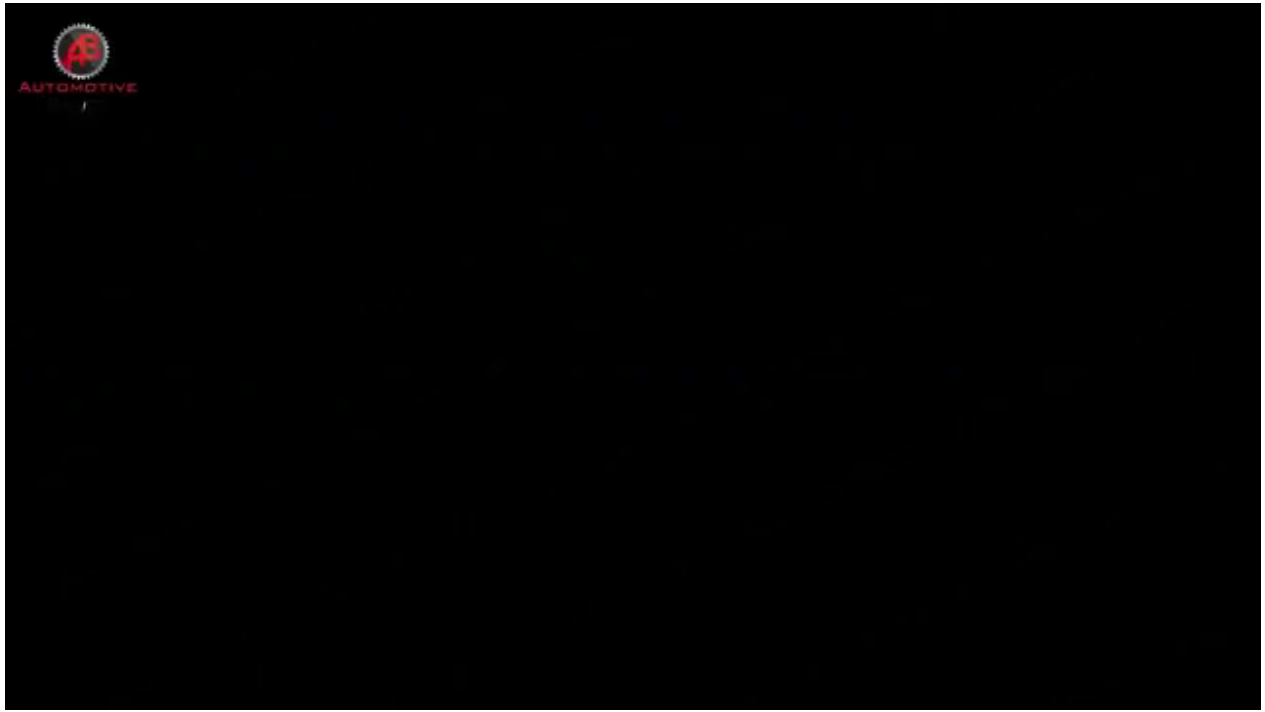
Engine Subsystems

https://www.youtube.com/watch?v=vIJ50aUiBgM&t=9s

Engine Subsystems

- Valve Operation
- Air Intake & Exhaust System
- Fuel Supply System
- Ignition System
- Lubrication System
- Cooling system
- Starting System

Indicator and valve-timing diagram for a 4- stroke SI engine



https://www.youtube.com/watch?v=Te-OltNQRUk

Indicator and valve-timing diagram for a 4- stroke engine

Terminology:

TDC:	Top dead center
BDC:	Bottom dead center
IVO:	Inlet valve opens (10°-20° before TDC)
IVC:	Inlet valve closes (30°-40° after TDC)
IGN:	Ignition (20°-30° before TDC)
EVO:	Exhaust valve opens (30°-50° before BDC)
EVC:	Exhaust valve closes (10°-15° after TDC)

Valve overlap: The duration (10°+10°=20°) when both inlet and exhaust valves remain open.

Spark Advance: The ignition is initiated 20° -30° before TDC.

Indicator and valve-timing diagram for a 4- stroke engine

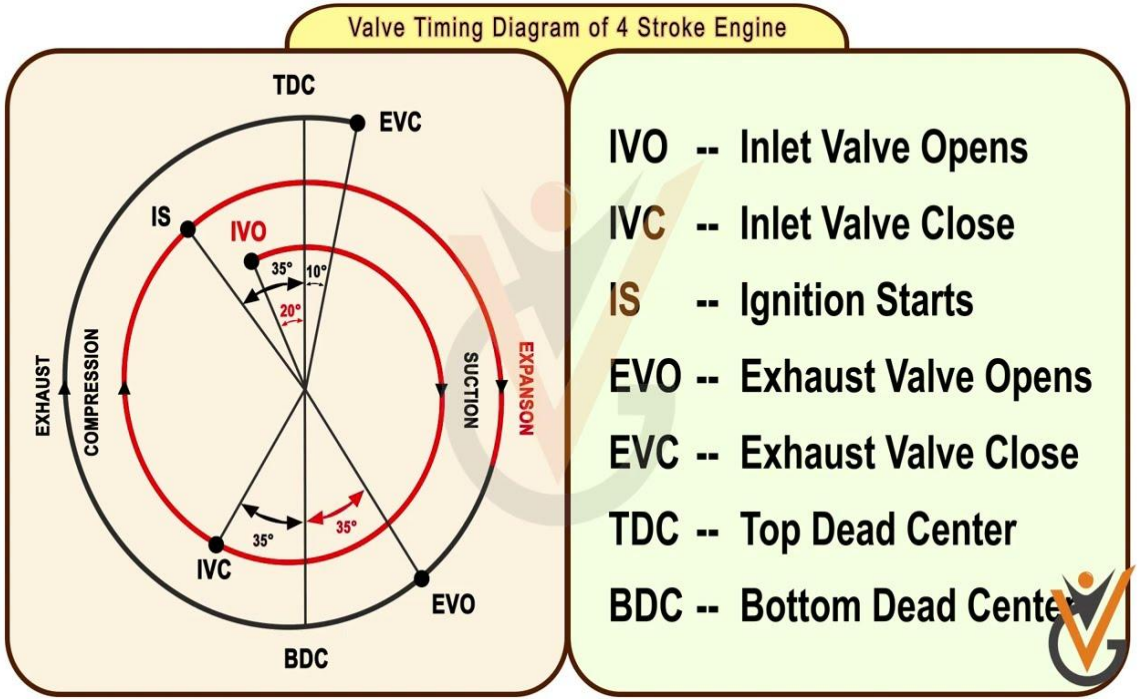


Figure: Valve timing for a four-stroke cycle engine.

Indicator and valve-timing diagram for a 4- stroke engine

- **Valve timing diagram:** The exact moment at which the inlet and outlet valve opens and closes with reference to the position of the piston and crank shown diagrammatically is known as valve timing diagram. It is expressed in terms of degree crank angle.
- ***Opening and closing of inlet valve***

  - Inlet valve opens 12 to 30° CA before TDC to facilitate full opening of the inlet valve by the time piston reaches TDC.

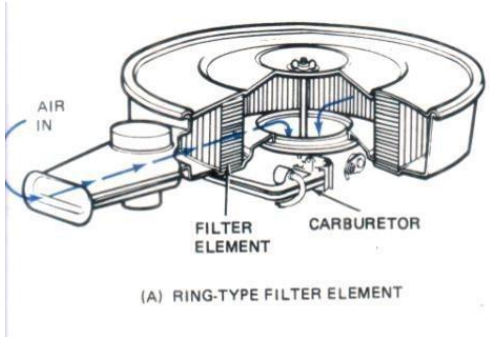
  -Inlet valve closes 10-60° CA after TDC due to advantage of the velocity of the Incoming gases, helping to continue filling the cylinder with additional air-fuel mixture even though the piston is moving back up the cylinder. This effect can be called ram effect. IVC one of the main factors in determining volumetric efficiency.

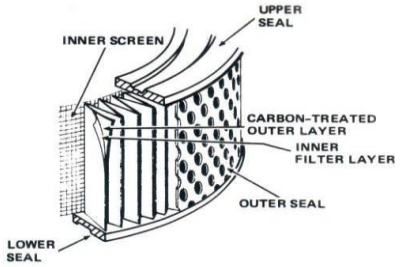
Indicator and valve-timing diagram for a 4- stroke engine

- ***Opening and closing of exhaust valve***
- Exhaust valve opens 25 to 55° CA before BDC to reduce the work required to expel out the burnt gases from the cylinder. This is called blowdown.
- Most of the power of the burning gases is delivered to the piston by about halfway through the power stroke so opening the exhaust valve at this point does not significantly reduce an engine's power output.
- Exhaust valve closes 10 to 30° CA after TDC to avoid the compression of burnt gases in next cycle. Kinetic energy of the burnt gas can assist maximum expelling of the gas. It also increases the volumetric efficiency.

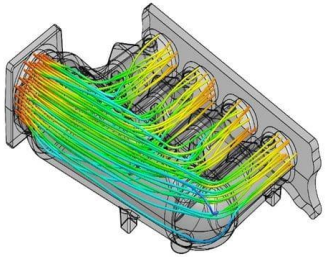
Air Intake & Exhaust System

- Air Intake System for taking fresh air from the atmosphere to be mixed with fuel for combustion

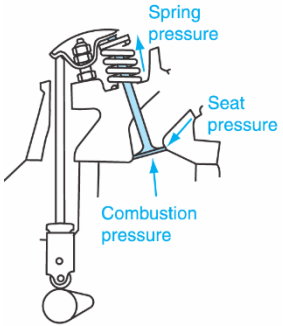




Air filter



Intake Manifold



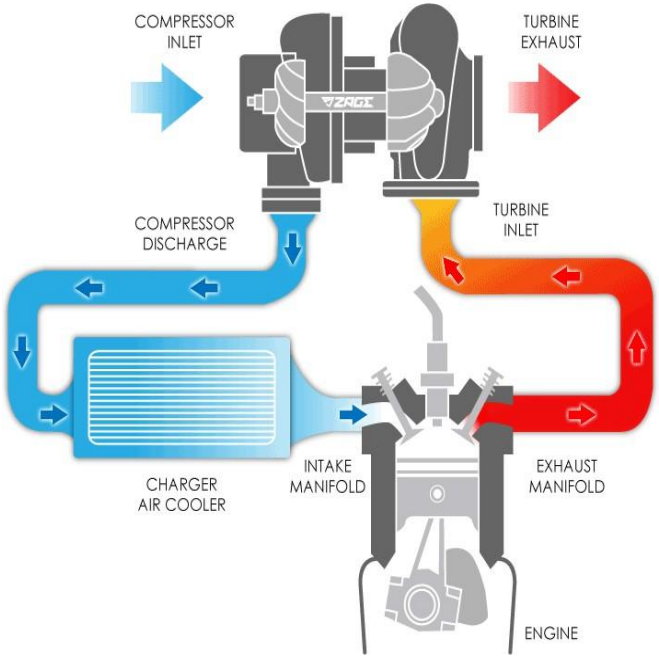
Intake Valve

Air Intake & Exhaust System

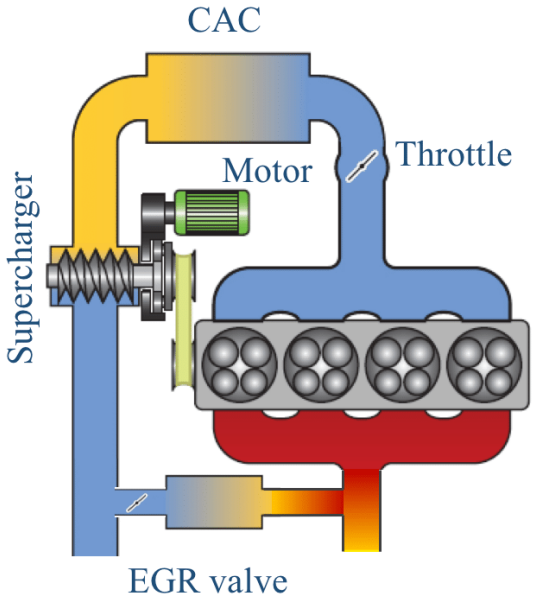
- **Normally Aspirated Intake:**
  which means that air flows through an air filter and directly into the cylinders. Most cars are normally aspirated.

- **Turbocharged & Supercharged Intake:**
  - Which means that air coming into the engine is first pressurized (so that more air/fuel mixture can be squeezed into each cylinder) to increase performance.
  - The amount of pressurization is called **boost**.
  - A turbocharger uses a small turbine attached to the exhaust pipe to spin a compressing turbine in the incoming air stream.
  - A supercharger is attached directly to the engine to spin the compressor intake.

Air Intake & Exhaust System



Turbocharged Engine

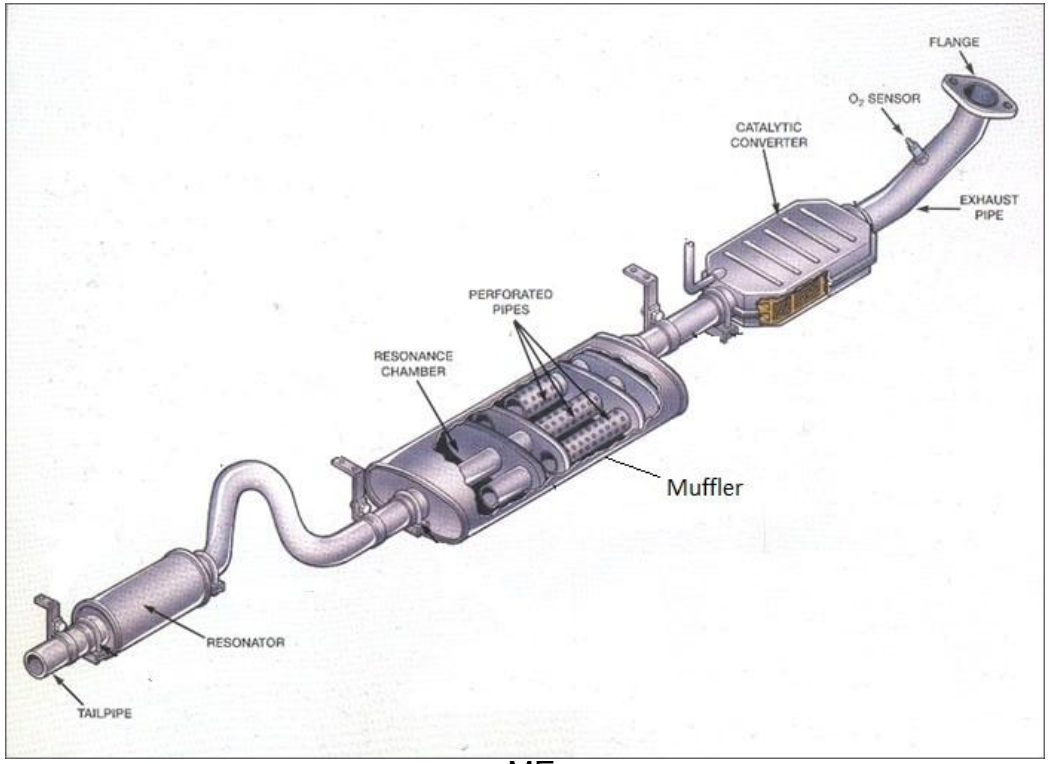


Supercharged Engine

Turbo lag: The delay in response when you press the throttle, and the effect of turbocharger takes place.

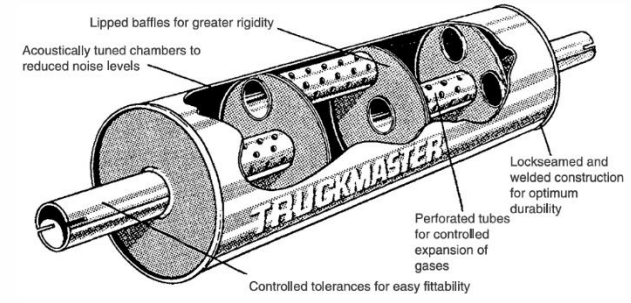
Air Intake & Exhaust System

- Exhaust System discharging the product of combustion from the engine.
- The exhaust system includes the exhaust manifold, pipe, catalytic converter, muffler and resonator.

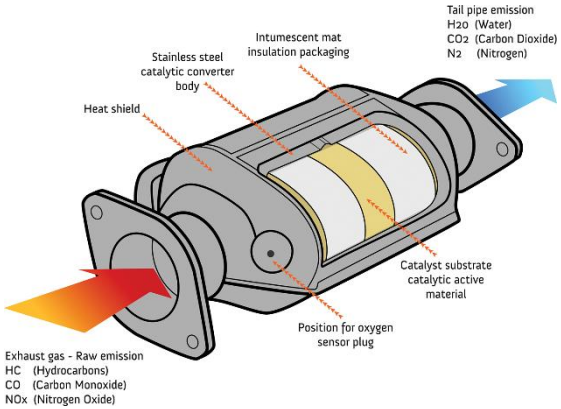


Air Intake & Exhaust System

Exhaust manifold



Silencer / Muffler

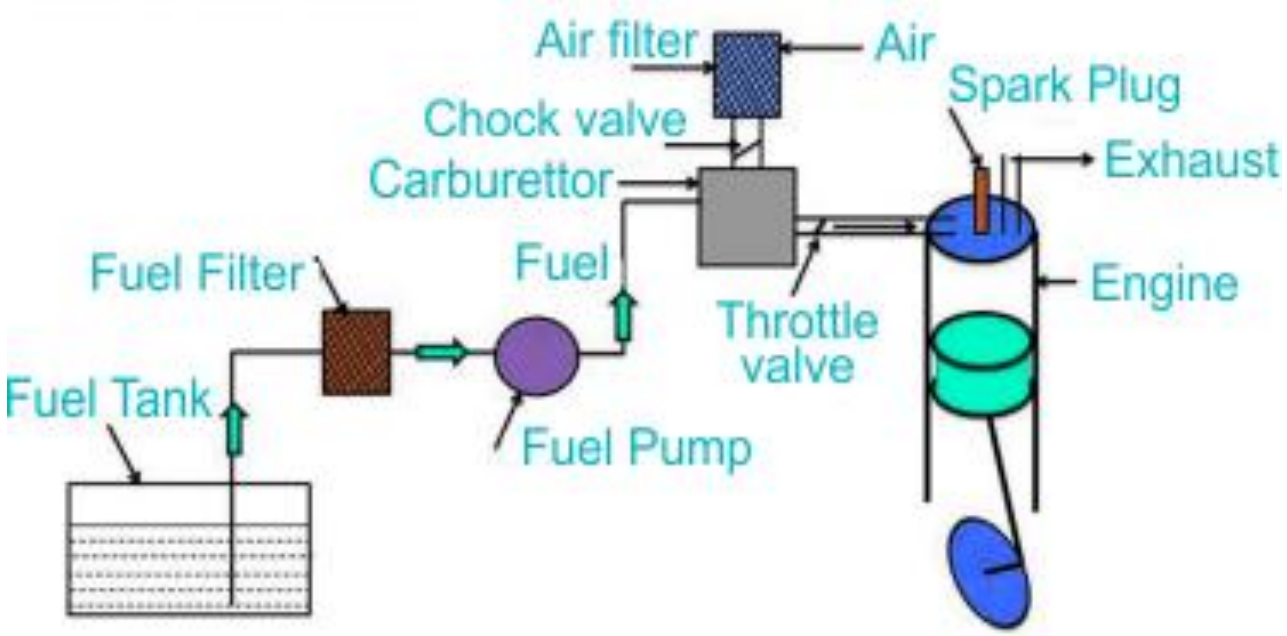


Catalytic Converter

Exhaust manifold: Attaches to the cylinder head and takes each cylinder's exhaust and combines it into one pipe. Typically made of aluminum or stainless steel.
Catalytic Converter: Converts harmful gases like CO, HCS, NOx to water vapor, carbon dioxide and nitrogen.
Muffler: To quiet the exhaust down to acceptable levels. The combustion process is a series of explosions that create a lot of noise. Mufflers use baffles to bounce the exhaust around dissipating the energy and quieting the noise.
Resonator: Helps reduce sound intensity level by cancelling out noises of certain frequency, also reduces the volume. Typically, consists of a specially made straight pipe.
O2 Sensor: To control the fuel injection rate and create the ideal air-fuel mixture.

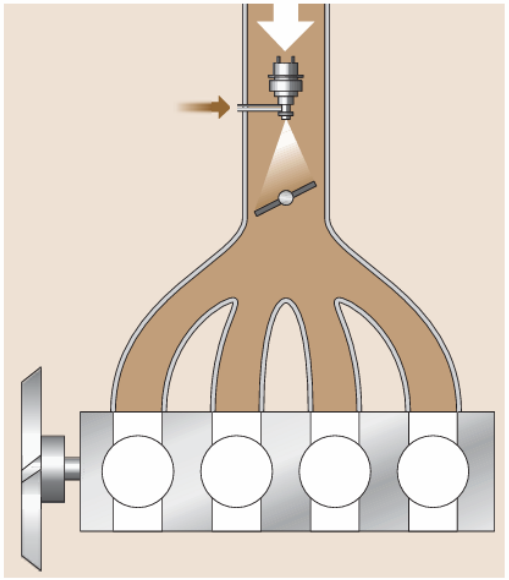
Fuel Supply System

- The fuel system pumps gas from the gas tank and mixes it with air so that the proper air/fuel mixture can flow into the cylinders.

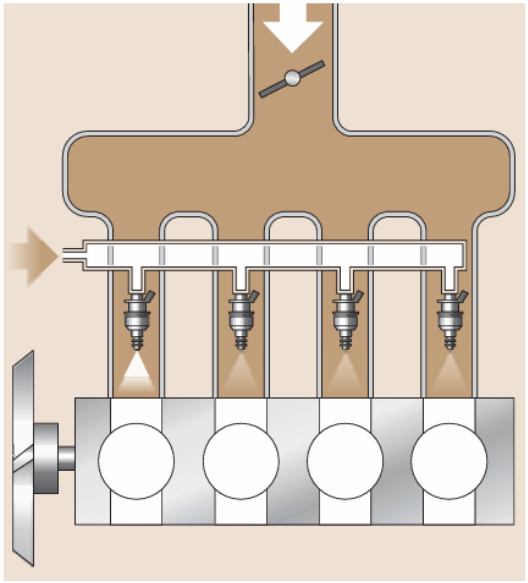


Fuel Supply System

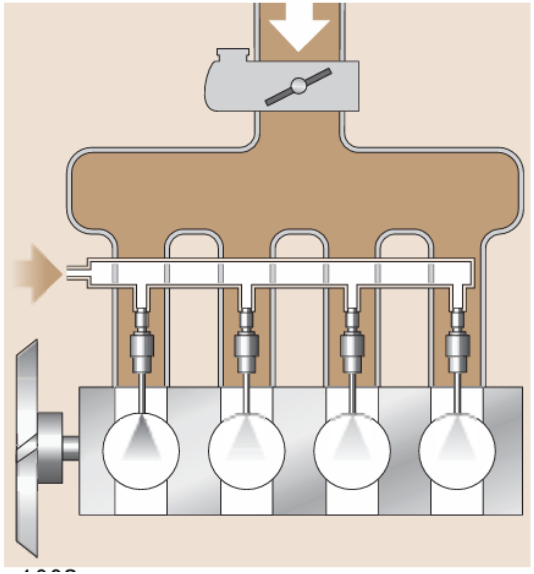
- Fuel is delivered in three common ways:
- Throttle body injection, port fuel injection and direct fuel injection.
- Carburetion used in old engines. (No fuel injector)



Throttle body

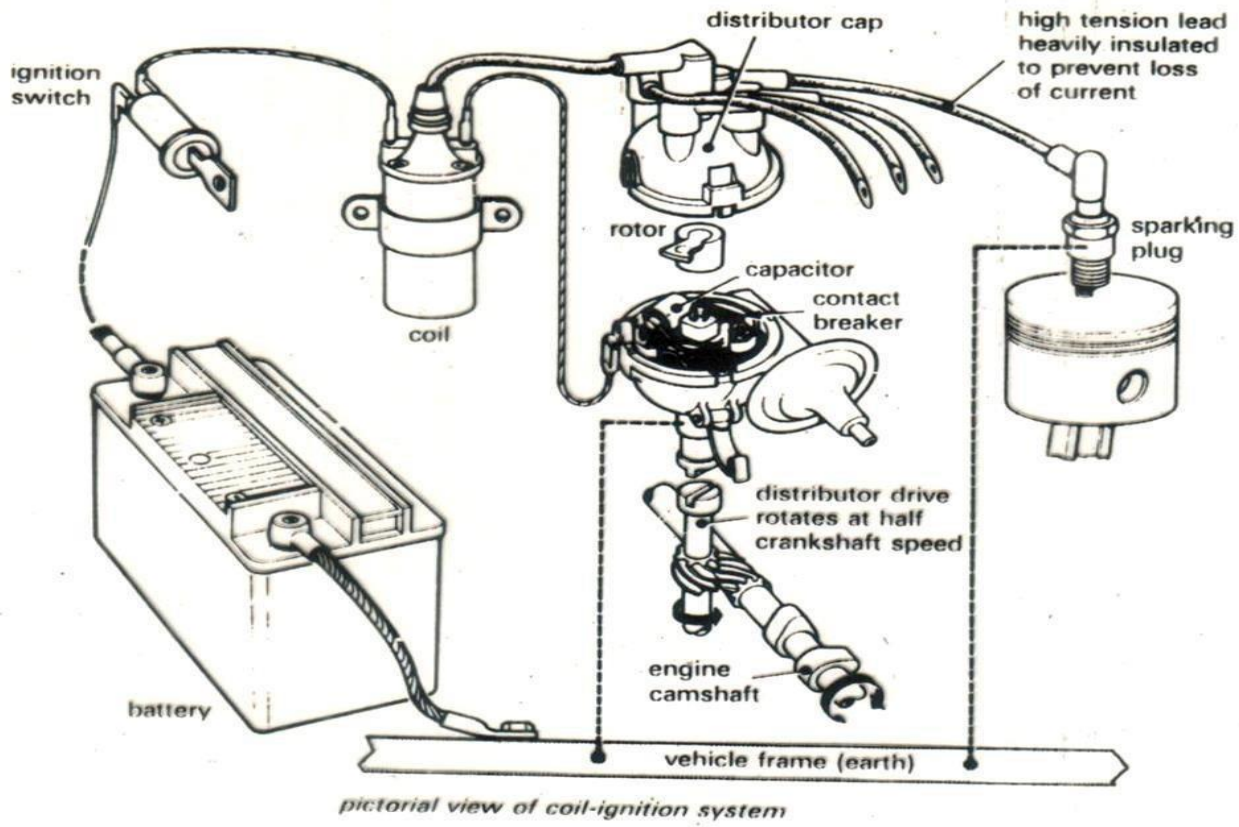


Port fuel injection



Direct fuel injection

Ignition System

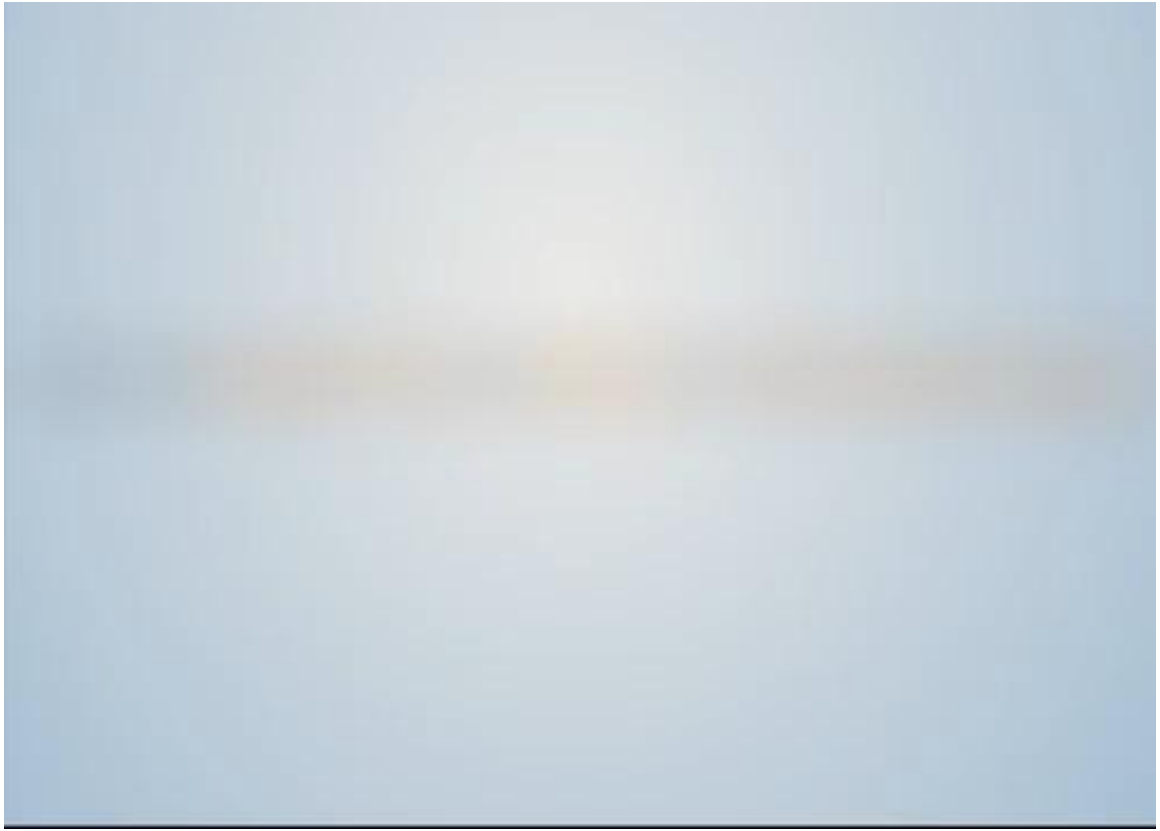


pictorial view of coil-ignition system

Ignition System

- The ignition system produces a high-voltage electrical charge and transmits it to the spark plugs via ignition wires.
- When the ignition switch is turned on the charge first flows from battery to a ignition coil to increase the voltage.
- Then the charge flows to a distributor. It distributes the charge to the spark plugs according to the firing sequence. The distributor has connected to four, six or eight wires (depending on the number of cylinders).
- These ignition wires send the charge to each spark plug.
- A very high voltage (20-24000 volt) is created between the spark gap which initiates the spark. The engine is timed so that only one cylinder receives a spark from the distributor at a time. This approach provides maximum smoothness.

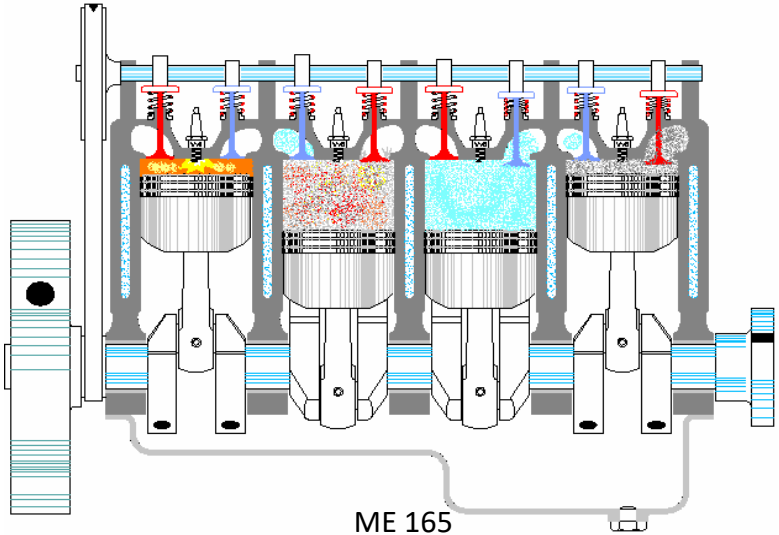
Ignition System



https://www.youtube.com/watch?v=OMLSNwQiiKg

IC Engine: Firing Order

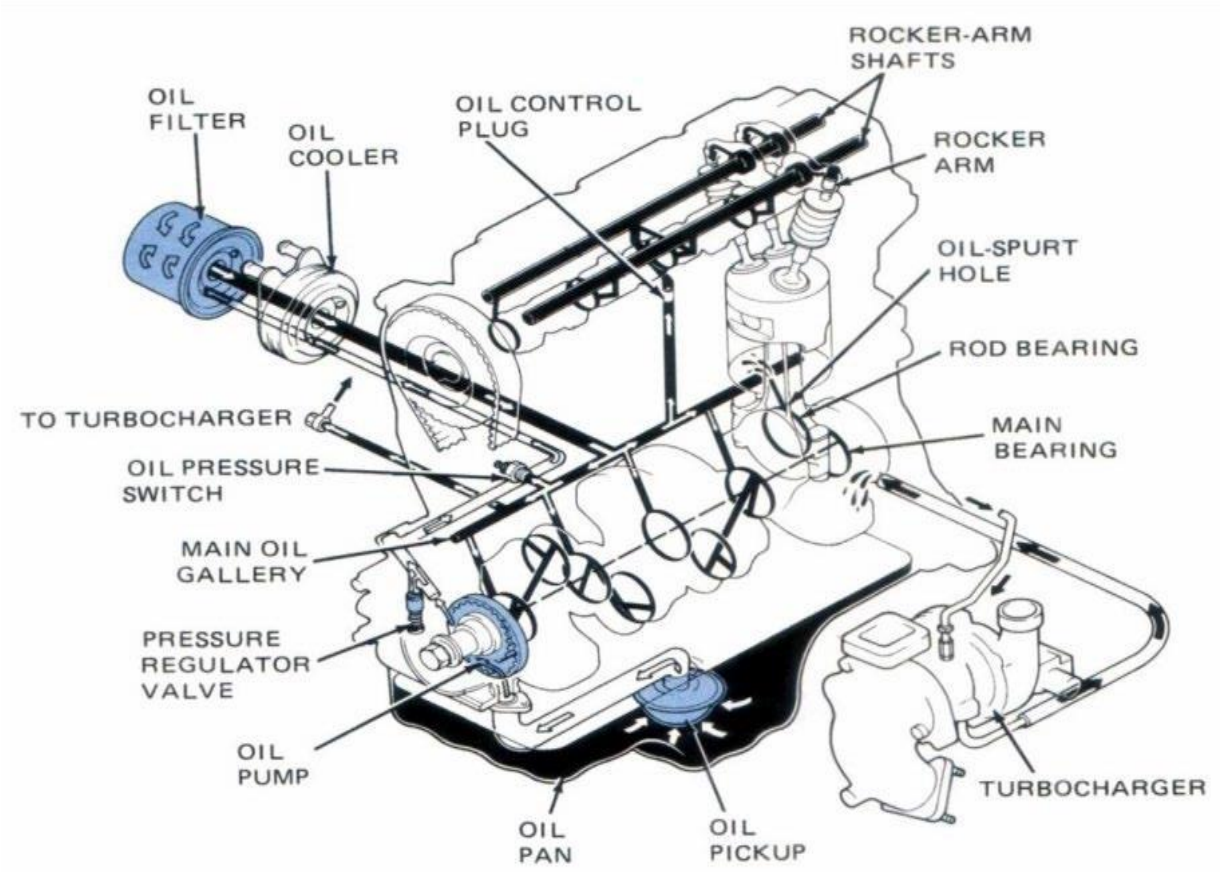
- Firing order: Inline four cylinder 1-4-3-2
- Firing order in a multi-cylinder engine is arranged so that the torsional moment is even and the load is uniformly distributed on longitudinal direction of the crankshaft. An even firing order will increase the balance of engine. Successive combustion in the cylinders that standing side by side should be avoided so that the force transmitted to the crankshaft does not become one-sided.



Lubrication System

https://www.youtube.com/watch?v=mmmcj53TNic

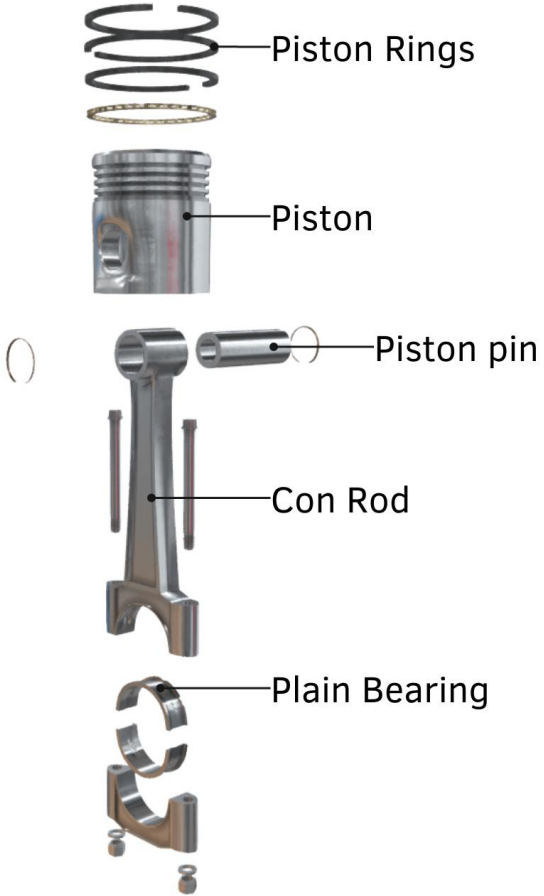
Lubrication System

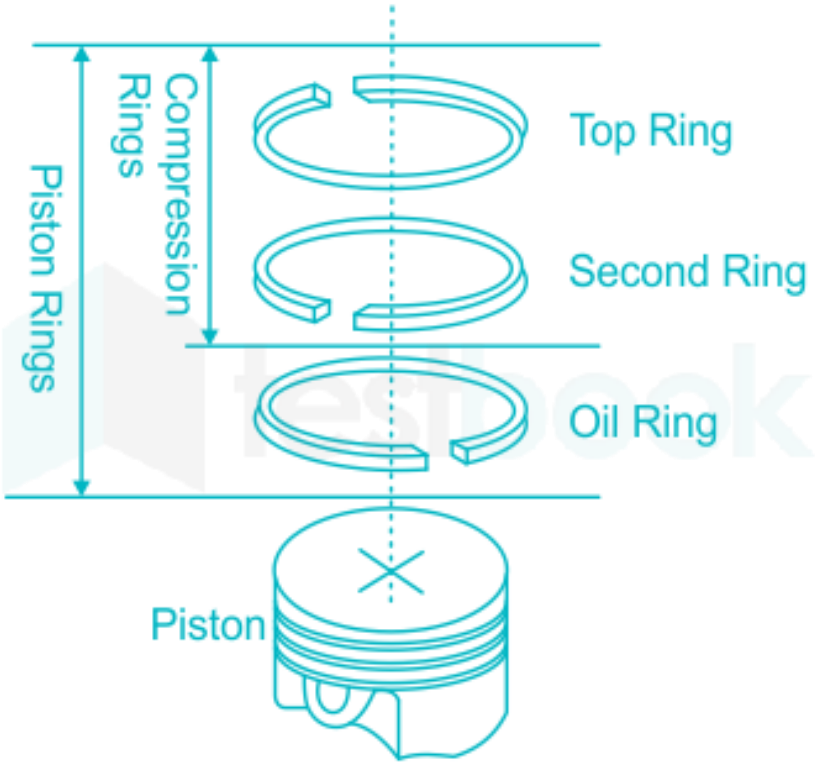


Lubrication System

- The lubrication system is necessary to ensure the proper movement of every engine part. The two main parts needing oil are the pistons and any bearings that allow things like the crankshaft and camshafts to rotate freely.
- **Process**: Oil is sucked out of the oil pan by the oil pump, run through the oil filter to remove any grit, and then squirted under high pressure onto bearings and the cylinder walls. The oil then trickles down into the sump, where it is collected again and the cycle repeats.

Lubrication System



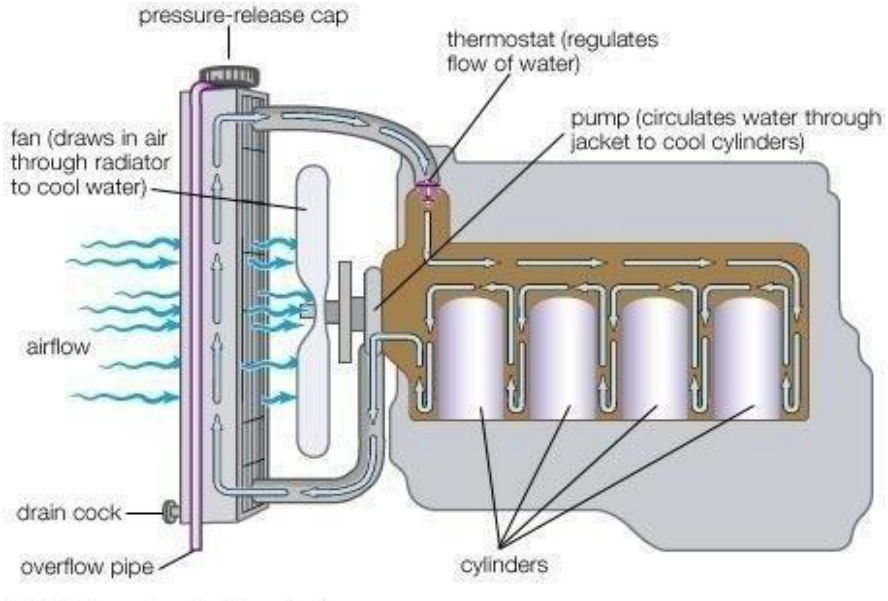


Functions of Lubrication System

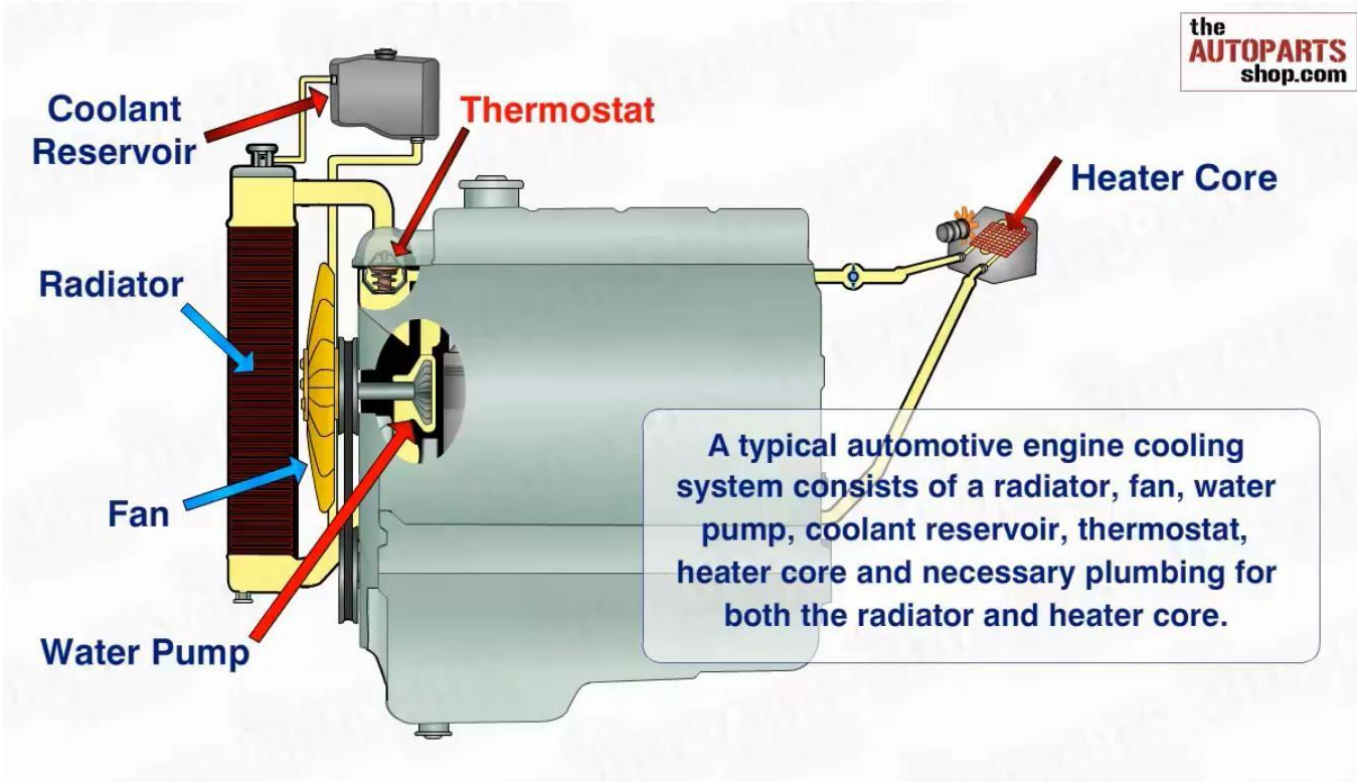
- Reduce wear of mating components
- Reduce frictional power losses
- Serve as a cooling agent
- Serve as a cleaning agent
- Better sealing
- Better cushion at bearings

Cooling System

- Cooling system in an IC engine can be classified as –
  - Air Cooled
  - Water Cooled



Cooling System

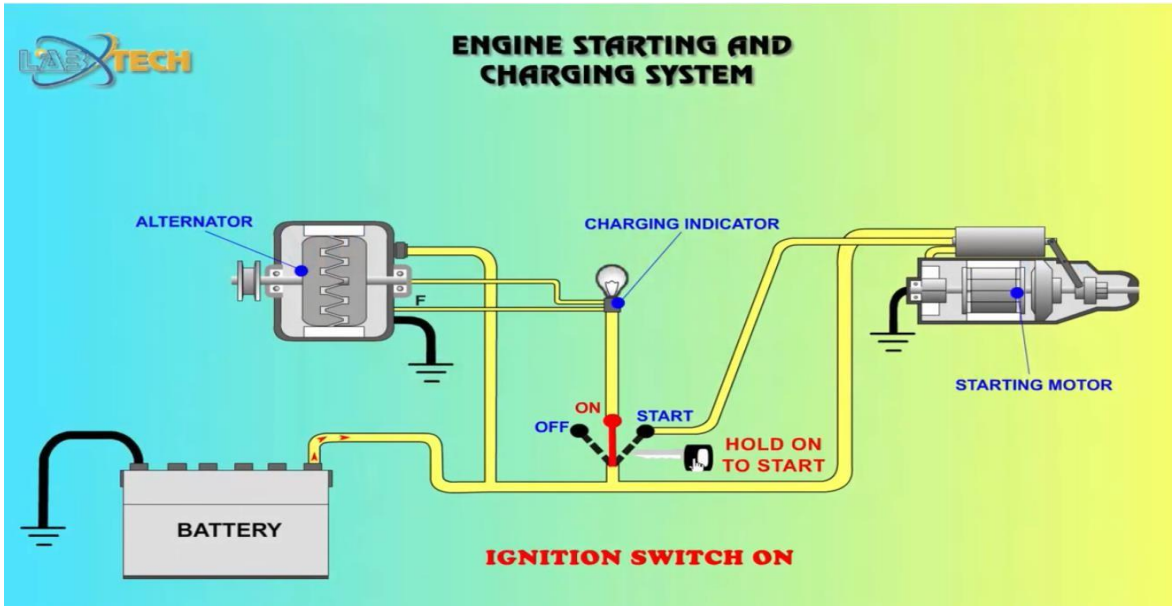


Cooling System

https://www.youtube.com/watch?v=V7inC4lOpGs&t=131s

Starting System

- The starting system consists of an electric starter motor and a starter solenoid.
- When you turn the ignition key, the starter motor spins the engine a few revolutions so that the combustion process can start.
- It takes a powerful motor to spin a cold engine.



Starting System

https://www.youtube.com/watch?v=EthVIixON4o

Starting System

- The starting system consists of an electric starter motor and a starter solenoid. When you turn the ignition key, the starter motor spins the engine a few revolutions so that the combustion process can start. It takes a powerful motor to spin a cold engine. The starter motor must overcome:
- All of the internal friction caused by the piston rings
- The compression pressure of any cylinder(s) that happens to be in the compression stroke
- The energy needed to open and close valves with the camshaft
- All of the components directly attached to the engine, like the water pump, oil pump, alternator, etc.
- Because so much energy is needed and because a car uses a 12-volt electrical system, hundreds of amps of electricity must flow into the starter motor. The starter solenoid is essentially a large electronic switch that can handle that much current. When you turn the ignition key, it activates the solenoid to power the motor

Summary

https://www.youtube.com/watch?v=9KKfIYch1FE

Acknowledgement

- Slide Courtesy:
- Dr. Aman Uddin, Assistant Professor, Department of Mechanical Engineering, BUET
- Saif Al-Afsan Shamim, Assistant Professor, Department of Mechanical Engineering, BUET