

## Basics of Mechanical Engineering-3

Prof. J. Ramkumar

Prof. Amandeep Singh Oberoi

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

Week 06

### Lecture 27: Basics of IC Engines

Friends, this lecture is going to be very interesting for you because we are going to talk about Engines, Electric and Hybrid Vehicles. This is where you sit and see the vehicles that are going around you. All these things work under the fundamental principles of thermodynamics. It's the zeroth law, first law, second law, and the third law.

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## Contents

- IC Engine
- 4 stroke Engine and 2 stroke Engine
- SI and CI Engine
- Electrical Vehicles
- Batteries
- Hybrid Vehicle
- IC Engine Vs Electric Vs Hybrid Vehicle



The content for today is going to be IC engines, then four-stroke engines, two-stroke engines. When you go to buy a vehicle, a two-wheeler, they say it is a two-stroke engine. So what is a two-stroke? What is a four-stroke? How does this difference come about? What is the impact on the customer when you drive on the road?

So that is something you would like to understand. Then SI engines and CI engines, spark ignition and compression ignition. Then electric vehicles, which are the talk of the town. And a lot of countries are investing heavily in electric vehicles. Nowadays, you can see electric charging points also coming into action.

Then come batteries. Then comes hybrid. A hybrid is a diesel plus electric vehicle, combined together in one vehicle. So finally, we will try to see the advantages of IC engines with respect to electric and hybrid vehicles.

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## IC Engine



- An Engine is a device that transforms one form of energy to another.  
E.g. A Heat engine converts thermal energy into mechanical energy.
- Engines are generally classified as:
  - 1 Internal Combustion engines (IC Engines) ✓
  - 2 External Combustion engines (EC Engines) ✓
- In External combustion engine, working fluid gets energy by burning fossil fuels or any other fuel outside the mechanical engine system, thus the working fluid does not come in contact with combustion products. E.g. Steam engine, where the working fluid is steam and the Stirling engine, where the working fluid is air.
- In an Internal combustion engine, combustion takes place within working fluid of the engine, thus fluid gets contaminated with combustion products.
- Petrol & Diesel engines are examples of internal combustion engine, where the working fluid is a mixture of air and fuel.



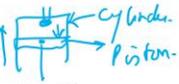
An engine is a device that transforms one form of energy into another. You pour fluid fuel there, and then there is a process—whatever happens in between—that's an engine, and then this engine tries to give you an output. This output is in terms of torque. That torque will be used to drive the vehicle. For example, 'drag' means you are all sitting—4 people, 6 people, 100 people, 50 people. And then the power that comes out through a shaft is attached to other things, like the transmission.

And then this is put inside a complete vehicle, and it tries to move. So, the energy is transformed from one form to another. A heat engine converts thermal energy into mechanical energy. Engines are generally classified into two types.

# IC Engine



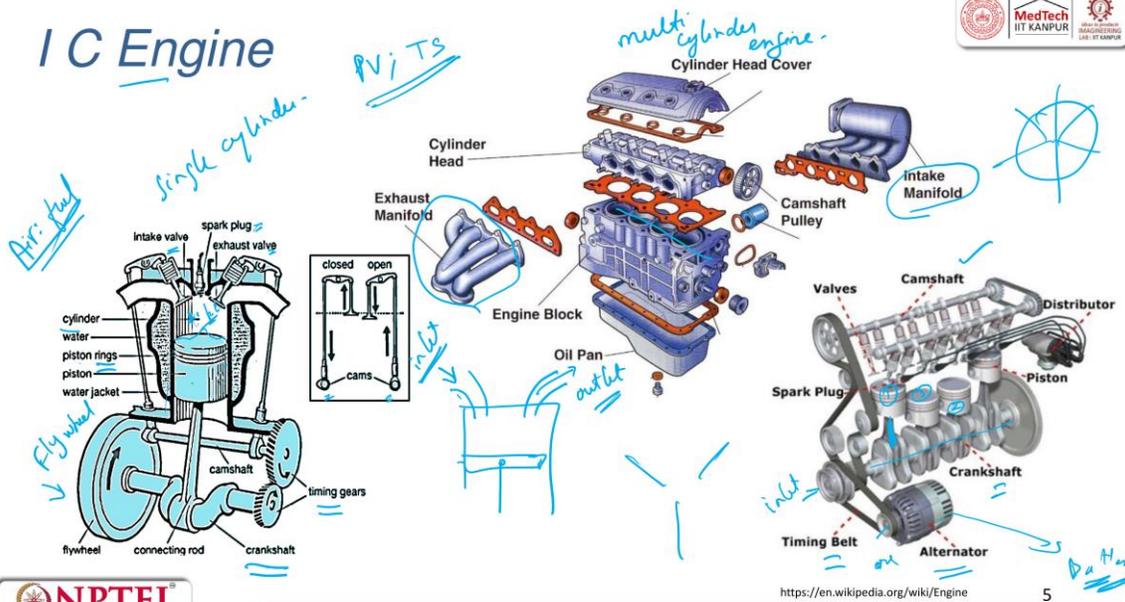
**Internal Combustion Engines are classified as:**

- On the basis of ignition :** Spark Ignition (SI engine) and Compression Ignition (CI engine), Multi Point Fuel Injection (MPFI engine).
  - Compression ✓
  - expansion ✓
  - Confined space ⇒ 
  - Pressure & Temp ↑
  - Air + Fuel ⇒ ratio
- On the basis of strokes :** 2-Stroke engine, 4-Stroke engine.
- On the basis of engine design :** Reciprocating engine, Rotary engine (single rotor and multi rotor).
- On the basis of cylinders :** Single cylinder engine, Multi cylinder engine.
- On the basis of working cycles :** Otto cycle engine, Diesel cycle engine, Dual cycle engine.
- On the basis of Fuel :** Petrol engine, Diesel engine, CNG Engine etc.



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# IC Engine



<https://en.wikipedia.org/wiki/Engine>

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One is the internal combustion engine, and the other is the external combustion engine. Internal combustion engines are very popular for their own advantages. In external combustion engines, the working fluid gets energy by burning fossil fuel or any other fuel outside the mechanical engine system.

Thus, the working fluid does not come in contact with the combustion products. Examples include steam engines, where the working fluid is steam, and Stirling engines,

where the working fluid is air. In internal combustion engines, the combustion takes place within the working fluid of the engine.

## I C Engine

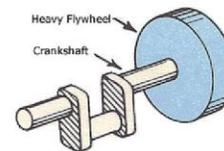
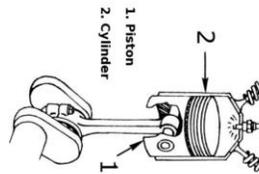


**Cylinder:** It is where the Combustion of fuel takes place and piston gains + transmits the power. It is made of hard and high thermal conductivity materials. *Handwritten notes: 1-20mt, P, V, T, mg*

**Water jackets:** The cavity paths through which cooling water is circulated to prevent overheating of the engine.

**Piston:** A cylindrical component fitted perfectly inside cylinder with piston rings and lubricants, that transmits the force exerted by the burning of fuel to the flywheel through the connecting rod and crank.

**Connecting rod:** It transforms the reciprocating motion of the piston in to rotary motion of the crankshaft.



<https://en.wikipedia.org/wiki/Engine> 6



Engine inside the engine. Thus, the fluid gets contaminated with combustion products. The petrol engines and diesel engines that you see in the market and on roads are all based on the principle of internal combustion engines. Here, the working fluid is a mixture of air and fuel. Internal combustion engines are classified as spark ignition.

Remember, there are only very simple processes: one is compression, and the other is expansion. All these things happen in a confined space. This confined space is nothing but a cylinder and a piston. This is a cylinder, and this is a piston. So, when the piston moves up, it compresses.

Because of the explosion or the ignition that happens in a compressed ratio, there is an expansion that occurs next. These are the two things. Compression, expansion, and then it is a confined volume. So what are the things that it can play? So the other thing that it can play is pressure and temperature.

Why does the temperature increase? When there is an ignition happening, because of the ignition, the expansion occurs. So the temperature increases, and the pressure reduces or

increases depending on the requirements. So this is all, friends, happening inside an engine. But when does it happen?

How does it happen is a question. When should a piston move up? What is the timing for it? These are all separate things that drive the system. But the principle is the same thing.

And as you know, there are only two things: air and fuel. So this leads to a ratio. So inside the cylinder, if I can maintain a ratio, then I will be able to get whatever is best out of the engine. So here, mechanical work is done, which is converted into power that is used for the rest of the transmission. So spark ignition is 1, and compression ignition is 2.

Compression ignition means when you go very close to the top end, the compression has attained its maximum. At that point, you can try to ignite, or at that point, there can be an ignition happening. So that's what compression ignition is. We can also have multipoint fuel injection today. Multipoint fuel injection engines mean, suppose all these things we are discussing are for one cylinder.

Suppose you have multiple cylinders—for example, three-cylinder, four-cylinder, six-cylinder, eight-cylinder—all these things are used. We generally use three-cylinder or four-cylinder in a car. So when you go to a marine application like boats or steamer boats, there can be two, four, or six, depending upon the power required and the load the engine has to take. On the basis of strokes, there are only two stroke, two stroke engine and four stroke engine which is generally used. And majority of the engines work on reciprocation moving back and forth.

Some of the engines are also there in rotary type. Reciprocation is piston moving up and down. So that is reciprocating engine. Rotary engines are also there. See, on the basis of cylinder, there can be single cylinder engine.

Single cylinder engine, for example, if you have a moped or if you have a TVS 50, which is very two-wheeler, where the engine cylinder is restricted to 50 cc, so there you have a single cylinder. And, friends, in drone, we can have two types of engines. One is you can have battery operated. The other one you can have a single cylinder engine. So here the biggest problem is you have to balance the timer so that what happens is when the drone flows, it should not jerk.

Majority of the drones are made out of electric, but some of them are also there with single cylinder engine, which gives you a longer duration as compared to that of the electric. You also have multi-cylinder engine. As I told you, all the cars are multi-

cylinder engines. On the basis of working cycle, it can be Otto cycle, which we have already discussed, Diesel cycle, it can be a Dual cycle. Otto cycle, Diesel cycle and Dual cycle. So, based on fuel, it can be petrol, diesel, or CNG.

Today, you are talking about hydrogen. People are even working on kerosene. Kerosene engines also exist. So, people get a kerosene engine, which is used to run a motor, so they try to install it on four wheels and attempt to drive a long distance. So, you can also use kerosene, but predominantly, what is approved by the government today are petrol, diesel, and CNG.

Hydrogen is on its way. So, these are different types of IC engines. This is a single-cylinder engine. This is a multi-cylinder engine. Where the output will have more power, here the output will be less power.

We were talking about the cylinder and piston, right? But when you look at it, it looks like a closed loop, right? Where the air—what happens to the air? Does the air get recirculated here? No.

So here, what has happened is you will have two ducts. So through one, you have an inlet, and the other you have an outlet, right? Inlet, outlet, right? So you have a single cylinder. So inside the cylinder, the piston moves up and down.

And when the piston moves up and down, it is connected to a rod. This, in turn, is connected to a shaft, which is called a crankshaft. And the crankshaft has two ends, right? The shaft has two ends: one end and the other end.

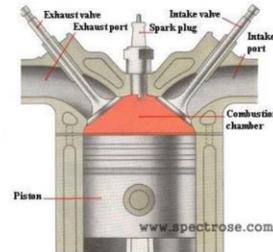
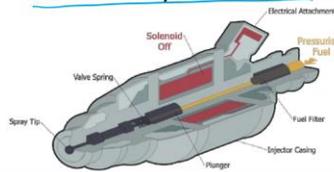
# I C Engine

① cylinders  
multi cylinders.



**Flywheel:** It is a heavy wheel mounted on the crank shaft. It absorbs the energy during power stroke and release it during non power stroke, thereby reducing the torque and speed fluctuations.

- **Inlet manifold:** It facilitates the inflow of fuel air mixture in the engine.
- **Exhaust manifold:** It facilitates the discharge of burnt fuel gases out of the engine.
- **Spark Plug:** In SI engine, it initiates the spark to cause fuel combustion.
- **Fuel injector:** It injects / supplies the metered quantity of fuel at high pressure in the cylinder of CI engine/ MPFI engine.
- **Fuel pump :** It supplies the fuel to the cylinder of the engine.



<https://en.wikipedia.org/wiki/Engine>

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The front end is attached to a flywheel, where the load and the energy can be stored and released. The other end is attached to a transmission system, which has the timing gears. Okay, these timing gears, if you see, are attached to a camshaft. This camshaft is used for opening and closing the fuel that enters the cylinder. Okay. So, as I told you, there is a cylinder.

This is a piston. The piston has metal-to-metal contact, right? Cylinder and piston. So, there is metal-to-metal contact. When you have metal-to-metal contact, you will not have a perfect seal.

So, you have piston rings attached to ensure a 100% seal, preventing air from flowing between the moving and static parts. That is the cylinder and the piston. Right. So, you have a piston that moves, and the piston is attached to a piston ring at the top. Though it looks flat, there is also something called a crown, which helps control combustion, air mixing, and exhaust.

Since there is a lot of heat generated here, there is a water jacket around it to cool the cylinder. This spark plug is used to ignite the air-fuel mixture. is used to ignite the air fuel mixture. So when the spark plug ignites, the temperatures will be exorbitantly high at the top dead center. So it will be more than 600, 700, 800 degrees Celsius.

But it is happening for a small fraction of a second. So now what people have started doing is, they have started changing the cast iron engine into aluminium such that the aluminium can fastly extract. It has a very high thermal conductivity. So it can fastly extract heat and throw it into the atmosphere. So and if you want to do it in a much faster rate, so then you have water jacket which is around it and this water jacket tries to remove it.

So here I was talking to you about cam. So this is a cam. The cam tries to control the opening and the closing of the tappet. This is a tappet which is on the top. So here it is very clear friends.

It is for a petrol engine. So here you will have air fuel mixture. Air-fuel mixture coming in between and this air-fuel mixture is used opening and closing can happen easily and then combustion happens here. This is for a petrol engine. So, now, let us move to the diesel, or this is also for a petrol.

So, this is for single, but now, if you have multi-cylinder, this is for a single cylinder, this is for a multi-cylinder. So, for a multi-cylinder, it is the same thing where 4 cylinders are there instead of 1. So, here it was exhaust valve 1. So, here, since there are 4, you will have exhaust manifold, which goes here. Then you will have inlet manifold because the air has to come through all these things.

You see these orange types. These are all sealants to have a proper metal to metal contact. So seal it so that the air does not leak. This is a cylinder head which was here cylinder head single and this is for multiple. So this is a basic and if you have 4 if you have 6 it is there.

Now these are all called as inline cylinders. You can also have in-plane cylinders, which means that three cylinders can be in one plane. Okay. So here, whatever I was talking to you about was a camshaft for opening and closing. So each cylinder—all the cylinders—will not be fired at once.

It will be fired at; see, if you take 360 degrees, it will be fired at varying angles. So each piston—one piston will be at the top, one will be at the bottom, one will be intermediate, whatever it is. Because all these four fellows, if they are very in-line at one time, then there will be a lot of vibration. In order to control the vibration, we have this type. So here, this will be done by a crankshaft.

The crankshaft will be attached to a connecting rod, which gets attached to a piston. So the pulling, opening, and closing will be done by the crankshaft. So this again will be attached to the flywheel and the timer gear we talked about. So this, in turn, is attached to an alternator. This alternator is used to energize your battery.

And you have a belt. So this belt is called a timer belt. So the other end, the timer belt gets the inlet from here, and this will be the outlet. So the alternator is run, and the battery is getting charged. So these are the things—all the technology—which work on the simple fundamentals of a PV diagram, which you see, and a TS diagram, which you have learned.

So, the IC engine cylinder is where the combustion of the fuel takes place, and the piston gains and transmits the power. It is made of hard, high-thermal-conductivity material: aluminium. And since it is a car, you have to carry the weight with you and move all the time. So now, what we do is try to make it lighter and lighter. So, aluminium is considered.

Magnesium is considered. Titanium is considered. But they are expensive. Aluminium. Sorry, it is Al.

Aluminium is considered; magnesium and titanium are better alternatives because their density is much lower than aluminium. So, people are trying to use titanium and magnesium, but aluminium is cost-effective. The water jacket, the cavity part, throws water through which cooling water is circulated to prevent engine overheating. As I told you, the piston moves, so you have only pressure and temperature; thus, the volume is constant. So, what you have are two variables: pressure increase, pressure decrease, and temperature increase and temperature decrease.

So when the temperature increases, there has to be a water-cooled jacket to reduce the temperature; otherwise, the material will get softened or it can lead to an explosion. The cavity path, through which the cooling water is circulated to prevent the overheating of the engine, is managed by the water jacket. Friends, in the initial trials, when the science was known and they were trying to convert it into technology, there were many engines that got blown off. Man evolved. Technology evolved.

Today, you sit and travel in a vehicle that goes at 120 kilometers per hour. Think of the piston movement—what happens. Think of the roller tappet movement—what happens.

The constant volume exhaust that goes through your exhaust. All these things have matured today.

It is an engineering marvel. You should appreciate it, friends, because science is something—from science to developing it into a technology. It's a huge challenge. The piston is another thing. The cylindrical component fitted perfectly inside a cylinder with piston rings and lubricants transmits the force exerted by the burning of the fuel to the flywheel through a connecting rod and crank, which I have explained in detail.

So if you want to see, this is a flywheel. This is a crankshaft, and this is a connecting rod which is attached. So you can see here, this is a crankshaft, and this is a connecting rod attached. The connecting rod transforms the reciprocating motion of the piston into the rotary motion of the crankshaft. So this is a flywheel, and this is a crankshaft which is attached.

So, the flywheel: the flywheel is a heavy wheel mounted on the crankshaft, on the other end of the crankshaft. It absorbs energy during the power stroke and releases it during the non-power stroke. So, I said you can have a single cylinder or you can have multiple cylinders, right? And in single-cylinder or multi-cylinder engines, you will have strokes, right? A stroke is nothing but this: one stroke. Moving up and down is called one stroke. So, you will have strokes in this, and all four strokes will not produce power.

So, there will be one stroke that produces power, and the other three: one will be for exhaust, one will be for power, and two will be intermediate. So what happens is the flywheel absorbs whatever energy is there and then slowly releases it. A flywheel is nothing but—if you have seen in many applications—like people used to have manual punching operations or manual compression injection operations. So what they do is they put everything there and then rotate a wheel. So this wheel rotates and then tries to deliver a lot of energy in one stroke.

So, the flywheel—what it does is it tries to absorb energy and then release it over a period of time. All these things happen in seconds, maybe a few seconds, or sometimes even milliseconds. The inlet manifold indicates the inflow of the air-fuel mixture into the engine. This is the inlet valve, exhaust valve, right? The inlet valve is the inlet manifold, as they call it.

It facilitates the inflow of the air-fuel mixture into the engine. The exhaust manifold is after the explosion happens; the spark ignites the compressed gas. Then, there will be

residue that has to be thrown out of the cylinder. So, it facilitates the discharge of the burned fuel out of the engine. The spark plug is the entity that gives a spark when there is a compressed air-fuel mixture in the cylinder piston.

The spark plug is used to spark and then create this. So this will try to initiate the combustion. Fuel injector or the fuel has to be injected into the cylinder at regular intervals of time. It injects and supplies the metered quantity of fuel at high pressure into the cylinder of a CI engine or a multi-point fuel injection engine. There are many cars today which follow that multi-point fuel injection.

The fuel pump supplies the fuel to the cylinder in the engine. So, this is, as I have already told you, the inlet manifold, exhaust manifold, and this is a typical setup for the spray. So, this happens in the CI engines, and this is for the SI engines. You have a spark plug there.

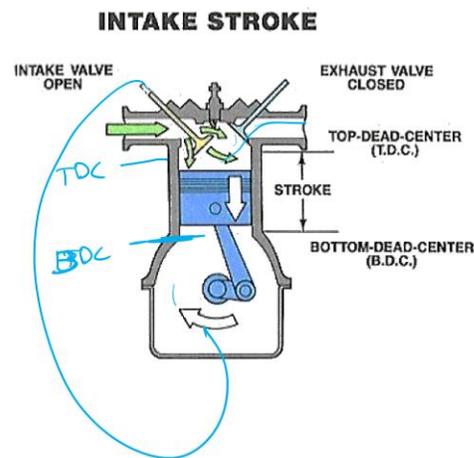
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## 4 Stroke Engine

A 4-stroke Diesel Engine working principle is explained hereunder.

### 1 Suction/Intake stroke

- During suction stroke, the inlet valve opens and the exhaust valve closes. The piston moves from Top Dead Centre (TDC) to Bottom Dead Centre (BDC).
- This piston movement reduces the pressure inside the cylinder below the atmospheric pressure.
- Due to the pressure difference, the fresh air is sucked into the cylinder through the inlet valve.



So now we will see what is four-stroke and two-stroke. The four-stroke diesel engine working principle is explained here under. So, the first one is the suction stroke or inlet stroke. During the inlet, it creates a vacuum so that the air can enter inside the cylinder. During the suction stroke, the inlet valve opens.

So now there are valves, right? So somebody has to come and open it. So this also has to be mechanized. And this will, in turn, be linked with the connecting rod and crankshaft.

This will be connected somewhere such that when the connecting rod rotates, right, or the crankshaft rotates, you will try to have opening and closing of the valve.

It is like a puppet show. You will have these pistons moving up and down, and the valves opening alternately. So, all these things are mechanically linked. And today, it is all electronically timed. So, there are many improvements happening.

So, there are sensors and electronic timers. So, this tries to gauge what is happening inside the cylinder and accordingly allows a limited amount of fresh air to come in. During the suction stroke, the inlet valve opens, and the exhaust valve is closed. Because when this is open and this is open through the exhaust valve, the fresh air mixture will go away. So, the piston moves from TDC (this is TDC) to BDC (this is BDC).

So, it moves from the top dead center to the bottom dead center. This piston movement reduces the pressure inside the cylinder below atmospheric pressure. See, there should be a vacuum, right? Then only the air can flow inside. Due to the pressure difference between the outside and inside, the fresh air is sucked into the cylinder through the inlet valve.

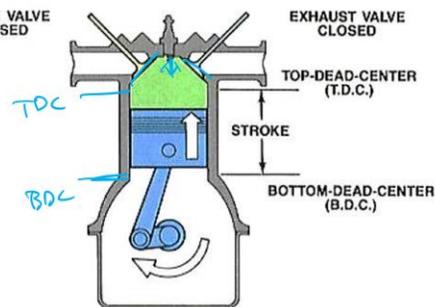
## 4 Stroke Engine



### 2. Compression Stroke:

- During this stroke, both the inlet and exhaust valves are closed.
- The air in the cylinder is compressed as the piston moves upwards from BDC to TDC.
- As a result of this compression, pressure and temperature of the air is increased.
- Just before the piston reaches the TDC, the diesel is injected into the cylinder in the form of a fine spray.
- The fuel gets vaporized and self ignited due to the heat of compressed air. The fuel burns instantaneously at constant pressure.

### COMPRESSION STROKE



Then you have a compression stroke. So, the compression stroke—what happens? You are trying to move the piston up. During the stroke, both the inlet and outlet valves, or the

exhaust valves, are closed. Once these two are closed, not only can you compress the air mixture inside.

The air in the cylinder is compressed as the piston moves from bottom dead center to top dead center. First, you absorb vacuum, then you compress, right? As a result of this compression, the pressure and temperature of the air increase. When it is compressed, I told you initially, the pressure increases as well as the temperature. Just before the piston reaches TDC, the diesel is injected because here compression is ongoing, ongoing, ongoing.

The cylinder is coming toward the top. There will be air that is getting compressed. So, when it is almost close to it, there will be an injection of diesel. So, as a result of this compression, the pressure and temperature of the air increase. Just before the piston reaches TDC, the diesel is injected into the cylinder in the form of a spray.

It can be injected, meaning it can be like pouring. When you try to pour diesel, a metered quantity, there is a possibility of rich pockets forming. To avoid that, we try to inject it. In injection, we take a metered quantity and convert the liquid fluid into spray particles. We spray it inside.

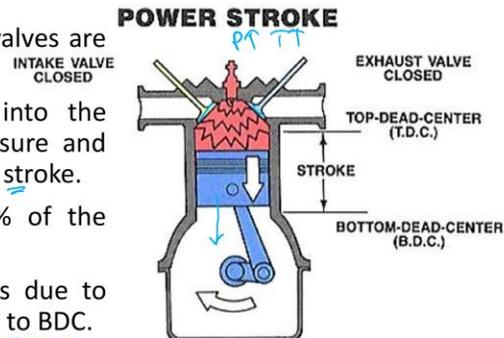
So that's what is injected—fine particles. Why do we do it as fine particles? Because each fine particle has surface area and volume. If the surface area is larger than the volume, the fuel can burn easily. Just before the piston reaches top dead center, diesel is injected into the cylinder as a fine spray.

The fuel vaporizes and self-ignites due to the heat of the compressed air. The temperature increase leads to burning the droplet, whatever it may be. So the fuel burns instantaneously at constant pressure because pressure increases after saturation occurs. Then it will burn all the fuel. Once all the fuel burns, there is huge pressure here, and the temperature will also be very high. The piston and cylinder cannot hold such things. Immediately, the next easing out will pull the piston down.

## 4 Stroke Engine

### 3. Expansion or Power Stroke:

- During this stroke, both inlet and exhaust valves are closed.
- The combustion of fresh fuel injected into the cylinder takes place due to the high pressure and temperature developed during compression stroke.
- The fuel is continuously injected for 20% of the expansion stroke.
- The high pressure of combustion products due to expansion of charge pushes piston from TDC to BDC.
- **In Petrol Engine, air-petrol mixture is injected in suction stroke and combustion is done by Spark from a spark plug.**



So then comes the expansion stroke or the power stroke. So after all the chaotic events have happened at the top, where the pressures and temperatures are high, the expansion must now occur. During this stroke, both the inlet and exhaust valves are closed.

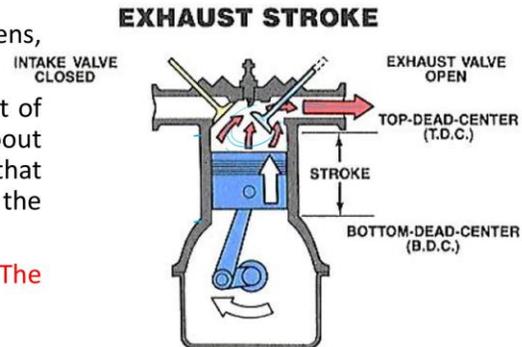
So they are not even open. So all these things happen when they are closed. The combustion of the fresh fuel injected into the cylinder occurs due to the high pressure and temperature developed during the compression stroke. The fuel is continuously injected for 20% of the expansion stroke. The high pressure of the combustion products, due to the expansion of the charge, pushes the piston from the top dead center to the bottom dead center.

This stroke is called the power stroke. In a petrol engine, the air-fuel mixture is injected during the suction stroke, and combustion is initiated by a spark using a spark plug.

## 4 Stroke Engine

### 4. Exhaust stroke

- During this stroke, the exhaust valve opens, the piston travels from BDC to TDC.
- This pushes most of the exhaust gases out of the cylinder into the exhaust system at about atmospheric pressure, leaving only that trapped in the clearance volume when the piston reaches TDC.
- With this stroke, one cycle completes. The engine works by repeating this cycle.



Then finally, the fourth stroke is the exhaust stroke. After everything happens, the combustion inside the cylinder must be expelled. It is like watching a movie in a theater.

So after the movie is over, all these people have to be moved out so that fresh people can come in. So all the combustion gas that is there has to be exhausted. So now the exhaust valve will be open and the inlet will be closed. During this stroke, the exhaust valve opens and the piston moves from BDC to TDC, bottom dead center to top dead center. Why?

Because it has to do something like scavenging, remove all these fellows out. This pushes most of the exhaust gas out of the cylinder into the exhaust system at about atmospheric pressure. So the pressure that comes out should be almost atmospheric pressure. If the pressures are low here and atmospheric pressure is high, then it cannot push. So it has to be slightly higher so that when it exits out, it gets into the atmospheric pressure, leaving only the trapped in the clearance volume when the piston reaches TDC.

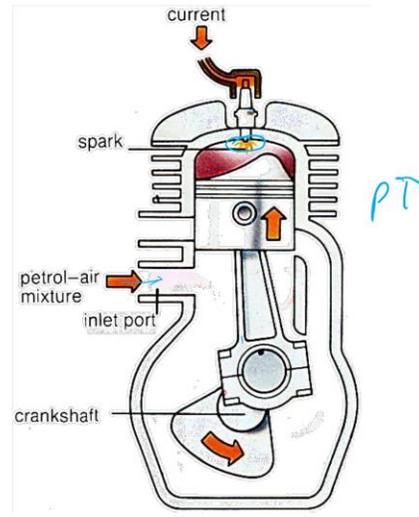
With this stroke, one cycle is complete and the engine works repeatedly through many cycles. Think of it, friends, when you go at 120 km per hour, what does this mechanical system do? This is for a 4-stroke engine. This is how a diesel engine works.

## Two Stroke Engine

A 2-stroke Petrol Engine working principle is explained hereunder.

### Stroke 1

- Air fuel mixture enters the crank case through inlet port.
- The air fuel mixture in the cylinder compressed.
- Towards the end of the stroke, the fuel air mixture is ignited using the spark from the spark plug.



Let's go for a two-stroke engine. The two-stroke petrol engine working principle is explained. So, stroke one: there are only two strokes. First, it has to take everything. The second one is the power stroke. The air-fuel mixture enters the crankcase through the inlet port.

This is the inlet port. So, the piston comes down through the inlet port. It tries to compress. The air-fuel mixture in the cylinder is compressed. So, pressure increases.

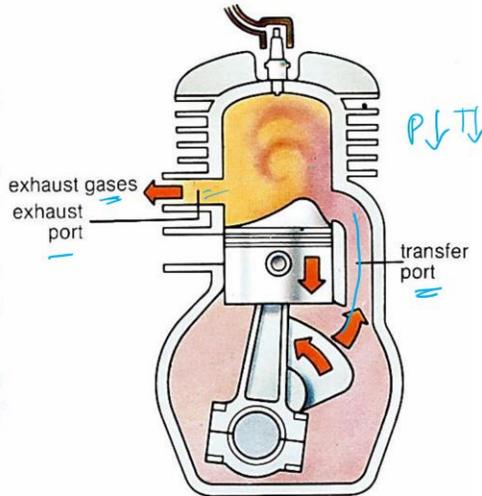
Towards the end of the stroke, the air-fuel mixture is ignited using a spark from the spark plug. So, it is ignited by a spark plug. So, at the end of the stroke itself, it does. So, what happens in two strokes happens here in one stroke. So, once it is done there, then there is combustion.

So there is a spark, there is a lot of combustion. So once the combustion is over, the pressures are moved down, the temperatures are moved down. So the piston is moved down from the top dead to bottom dead. So it is pulled down. When it is pulled down, what happens? The first thing what comes in the line is exhaust.

## Two Stroke Engine

### Stroke 2

- Piston moves downward due to the expansion of the gases
- Near the end of stroke, piston uncovers exhaust port and burnt gases escape through the port.
- Transfer port is uncovered and compressed air fuel mixture from the crankcase flows in to the cylinder.
- So, 2 strokes complete one cycle for this engine and such cycles repeat for continuous power transmission.



So through exhaust, the combust gas goes away. The piston moves downward due to the expansion of the gas. Near the end of the stroke, the piston uncovers the exhaust port. So here in a four-stroke, you have inlet, outlet tappets, right?

So here you have inlet and outlet valves. So it will close and it will go. Near the end of the stroke, it uncovers the exhaust port, and burnt gas escapes through the port. The transfer port is uncovered, and the compressed air-fuel mixture from the crankcase flows into the cylinder. So this is the transfer port, inlet, and outlet.

The transfer port is uncovered, and compressed air-fuel from the crankcase flows into the cylinder. So, a two-stroke completes one cycle for this engine, and such cycles repeat continuously for power transmission. So now, friends, you will easily differentiate what a four-stroke engine and a two-stroke engine are.

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## Two Stroke Engine

### Advantages

- Two-stroke engines have a simpler, lighter design because they don't use valves, and they provide more power by firing every revolution (unlike four-stroke engines).
- They deliver more uniform torque and can use a lighter flywheel since there are more power strokes per revolution.

### Disadvantages

- These engines have shorter lifespans due to poor lubrication and require mixing engine oil with gasoline.
- They are less efficient in fuel usage and produce high levels of pollution.

The advantage of a two-stroke engine: two-stroke engines are simpler, lighter in design because they do not use valves, and they provide more power by firing every revolution. They deliver more uniform torque and can use lighter flywheels since there are more power strokes per revolution.

But the disadvantage is that the engines have a shorter lifetime because there is no lubrication happening. And they are less efficient because, as you see here, the exhaust has some synchronization happening. So, the fuel, the air-fuel mixture, is also lost. They are less efficient in fuel usage and produce a high level of pollution. So when we compare a two-stroke and a four-stroke engine: the number of strokes per cycle is four for the four-stroke, and two for the two-stroke.

## Four-stroke Vs Two-stroke Engine



PARAMETERS	4 STROKE ENGINE	2 STROKE ENGINE
No of Strokes per Cycle	Four	Two
No of Revolutions of Crank per cycle	Two	One
No of Cycles per min	$n = N/2$ $N = \text{Engine Speed}$	$n = N$
Power Derived	In every alternate revolution of crank shaft	In every revolution of crank shaft
Direction of rotation of Crankshaft	Crankshaft Rotates in One Direction	Crankshaft Rotates in Either Direction
Valves / Ports	Inlet, Exhaust Valve Operated by cam using Valve – Gear Mechanism	Inlet, Transfer & Exhaust Port are in Cylinder Walls Piston Movement Covers & Uncovers the Ports
Torque Fluctuations	High	More Uniform



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## Four-stroke Vs Two-stroke Engine



PARAMETERS	4 STROKE ENGINE	2 STROKE ENGINE
Flywheel	Heavy Flywheel due to Non Uniform Torque on the Crankshaft	Lighter Flywheel is enough due to Uniform Torque
Admission of the Charge	Charge is Directly admitted into cylinder during Suction Stroke	Charge is Admitted into the Crankcase and then Transferred to the cylinder
Exhaust of products of Combustion	Due to upward movement of the piston during Suction Stroke	Due to Scavenging
Fuel Consumption	Less	More
Mechanical Efficiency	Low	High
Noise	Less	More
Engine Size	Heavy & Bulky	Compact
Initial Cost	High	Low
Uses	Buses, lorries, Trucks & Cars	Motorcycles, Scooters, Mopeds, etc.



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The next one is the number of revolutions of the crank per cycle, which is two for the four-stroke and one for the two-stroke. The number of cycles per minute is  $n = N/2$  for the four-stroke and  $n = N$  for the two-stroke, where  $N$  is the engine speed. So, friends, this is why the dashboard always shows the engine speed. The power is derived in every alternative revolution of the crankshaft for the four-stroke. For the two-stroke, power is derived in every revolution of the crankshaft.

Direction of rotation of the crankshaft: the crankshaft rotates in one direction or either direction. There are valve ports. The inlet and exhaust valves operate via a cam using valves and a gear mechanism. Here, the inlet, transfer, and exhaust ports are in the cylinder. Valve and piston movement cover and uncover them in the piston itself. So, you will have more mechanical parts here.

Torque fluctuation is very high in a 4-stroke engine and very uniform in a 2-stroke engine. The flywheel stores energy. A heavy flywheel is needed due to non-uniform torque on the crankshaft, while a lighter flywheel is used for uniform torque. Admission of charges. The charge is directly admitted into the cylinder during suction. The charge is admitted into the crankcase and then transferred to the cylinder.

Exhaust occurs due to the upward movement of the piston during the suction stroke. There is an exhaust here due to the scavenging process. Fuel consumption is less in a four-stroke engine but higher here because energy is lost due to the rich mixture and the inlet, outlet, and transfer ports. Mechanical efficiency is low in one and high in the other. Noise is less in one and more in the other. It is heavy and bulky versus compact. Initial cost is high versus low. Used in buses, lorries, and trucks versus motorcycles, scooters, and mopeds. So, this is an SI engine, and this is a CI engine.

## SI & CI Engines

Based on mode of ignition, engines are also termed as Spark Ignition and Compression Ignition engine.

- (SI) engine, commonly known as a petrol engine, is a type of internal combustion engine that uses a spark plug to ignite a compressed fuel-air mixture. SI engines are widely used in vehicles like cars, motorcycles, and small aircraft etc.
- In CI engine, fuel ignition is achieved by the high temperature of compressed air. Typically using diesel fuel, CI engines are known for their high efficiency, durability, and ability to produce significant torque. It is commonly used in trucks, buses, ships and industrial generators (DG sets).



## SI vs CI Engines

Description	SI Engine	CI Engine
Basic cycle	Works on Otto cycle or constant volume heat addition cycle.	Works on Diesel cycle or constant pressure heat addition cycle.
Fuel	Gasoline, a highly volatile fuel. Self-ignition temperature is high.	Diesel oil, a non-volatile fuel. Self-ignition temperature is comparatively low.
Introduction of fuel	A gaseous mixture of fuel-air is introduced during the suction stroke. A carburettor and ignition system are necessary. Modern engines have gasoline injection.	Fuel is injected directly into the combustion chamber at high pressure at the end of the compression stroke. A fuel pump and injector are necessary.
Load control	Throttle controls the quantity of fuel-air mixture introduced.	The quantity of fuel is regulated. Air quantity is not controlled.
Ignition	Requires an ignition system with spark plug in the combustion chamber. Primary voltage is provided by either a battery or a magneto.	Self-ignition occurs due to high temperature of air because of the high compression. Ignition system and spark plug are not necessary.

So here, based on the mode of ignition, the engine is also termed as a spark ignition or compression ignition engine, depending on the mode of injection. SI, commonly known as a petrol engine, is a type of internal combustion engine that uses a spark plug to ignite the compressed air-fuel mixture. They are widely used in small vehicles. CI: The fuel injection is achieved by the high temperature of compressed air. Typically using diesel fuel, CI engines are known for their high efficiency and durability.

So the comparison is done for SI and CI engines. It works on the Otto cycle. It works on the Diesel cycle. The fuel is volatile in SI engines, such as petrol, whereas in CI engines, it is diesel, which is a non-volatile fuel. The introduction of the fuel: The air-fuel mixture is introduced during the suction stroke.

The fuel is injected directly into the combustion chamber at high pressure at the end of the compression stroke. So please see this; this is very important. The load control is throttle control of the air-fuel mixture quality. So the quality of the fuel is regulated. Ignition happens through a spark plug. Here, self-ignition occurs at the high temperature of the compressed air.

And thank you very much.