LANDMARK UNIVERSITY, OMU-ARAN

LECTURE NOTE 3
COLLEGE: COLLEGE OF SCIENCE AND ENGINEERING
DEPARTMENT: MECHANICAL ENGINEERING
Course code: MCE 211
Course title: Introduction to Mechanical Engineering
Credit unit: *2 UNITS.*
Course status: *compulsory*
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OBJECTIVE:

The aim of this technical report is:
1 - Introducing different types of internal combustion engines, based on different categorization.
2 - Familiarization with the mechanism of operation of each, and the thermodynamic relations behind its theoretical cycles.

GENERAL ASPECTS ABOUT ENGINES MECHANISM:

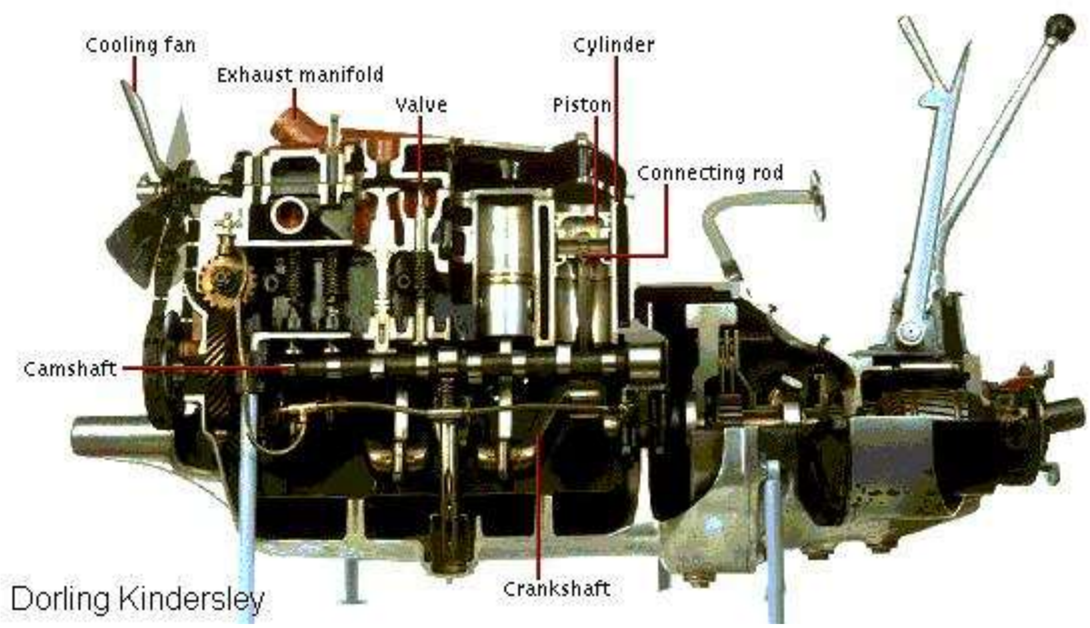

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Figure 1

An Early Internal Combustion Engine

The above image is an early design for internal combustion four-stroke four-cylinder engine. The main idea for any engine is the existence of a combustion chamber, in which fuel-air mixture exists. Then, this mixture is allowed to burn; either using a spark or by increasing its temperature and pressure of the mixture. Due to combustion, energy is liberated and the piston is forced to move. Accordingly, it transforms the produced power to the gearbox using the crankshaft. It should also be noted that air is allowed to enter and mix with the fuel using the camshaft mechanism.
As previously mentioned, the main difference between the engines are either the number of strokes or the cycle that is used to ignite the fuel.

STROKE CATEGORIZATION

The stroke is defined as the length of the path that the piston goes through inside the cylinder. The upper end of the cylinder is referred to as the Top Dead Center (TDC), and the lower end is referred to as the Bottom Dead Center (BDC). Using the crankshaft mechanism, the linear motion that comes out from the piston due to the combustion is converted into rotational motion. Rotational motion is the required one to drive the wheels.
Following is the explanation of the two-stroke and four-stroke engines.

TWO-STROKE ENGINES:

Two stroke engines are normally found in low power vehicles, such as: garden equipment, jet skis, and some motorcycles engines. From its name, the two-strokes engine refers to a type of an engine in which the process of combustion of a fuel and the liberation of mechanical energy takes place in only two strokes of the piston, the first goes from the top dead center to the bottom dead center, and vice versa for the second stroke.
Starting from the point at which compressed fuel/air/oil mixture exists inside the piston, a spark is ignited from the spark plug, hence combustion. Combustion produces large energy that pushes the piston downward and exhaust gases are formed out of the combustion. Thus, the engine starts its first stroke in which it delivers power using the crankshaft and exhaust gases are liberated out of the cylinder from the exhaust valve.

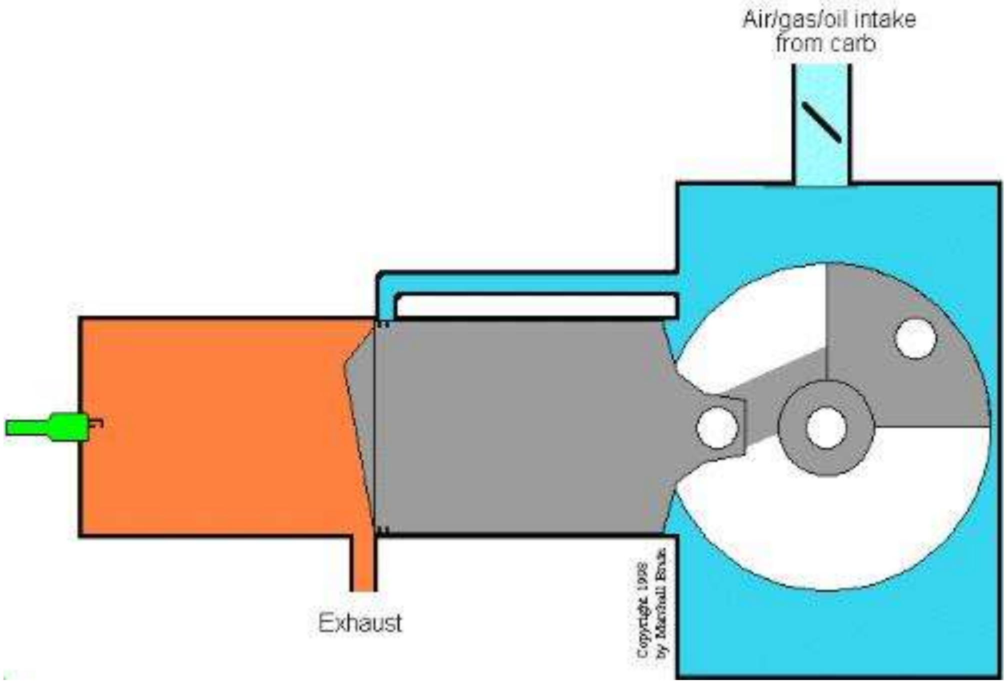


Figure 2
First stroke of the 2-stroke engine

As the piston proceeds downward, another valve is opened which is the fuel/air valve. Air/fuel/oil mixtures come from the carburetor, where it was mixed, to rest in an adjacent fuel chamber. When the piston moves downward more and the cylinder has no more gases, fuel mixture starts to flow to the combustion chamber and the second process of fuel compression starts. It is worth mentioning that the design carefully considers the point that fuel-air mixture should not mix with the exhaust. Therefore, the processes of fuel injection and exhausting should be synchronized to avoid that concern.

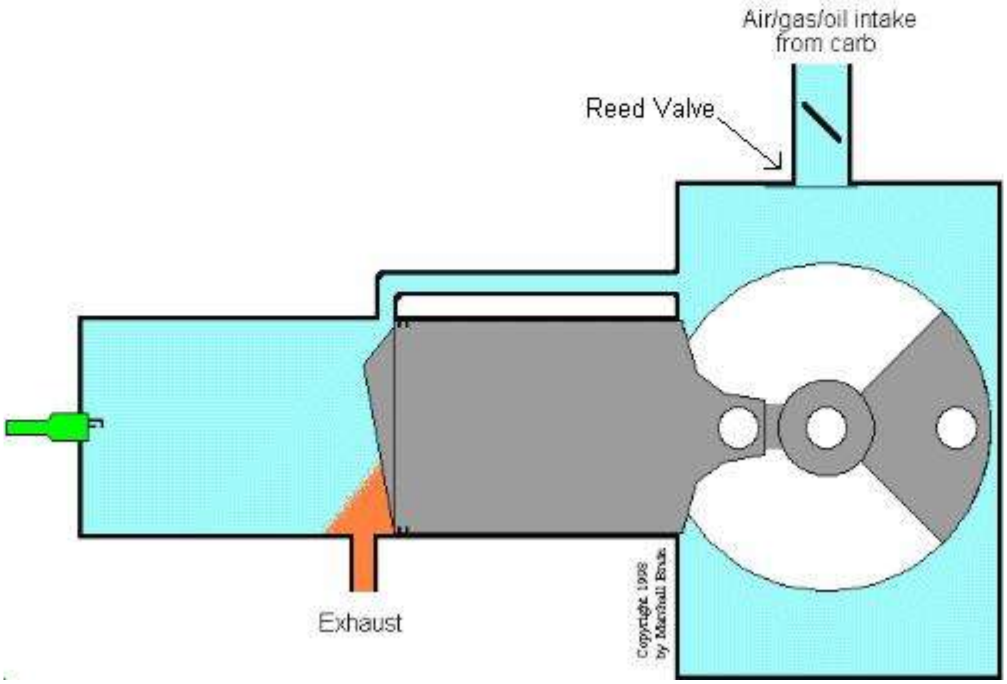
It should be noted that the piston has three functions in its operation:

1 - The piston acts as the combustion chamber with the cylinder, and it also compresses the air/fuel mixture and receives back the liberated energy and transfers it to the crankshaft.

2 - The piston motion creates a vacuum in order to such the fuel/air mixture from the carburetor, and pushes it from the crankcase (adjacent chamber) to the combustion chamber.

3 - The sides of the piston are acting like the valves, covering and uncovering the

intake and exhaust ports drilled into the side of the cylinder wall.



ADVANTAGES AND DISADVANTAGES OF THE 2-STROKE ENGINE:

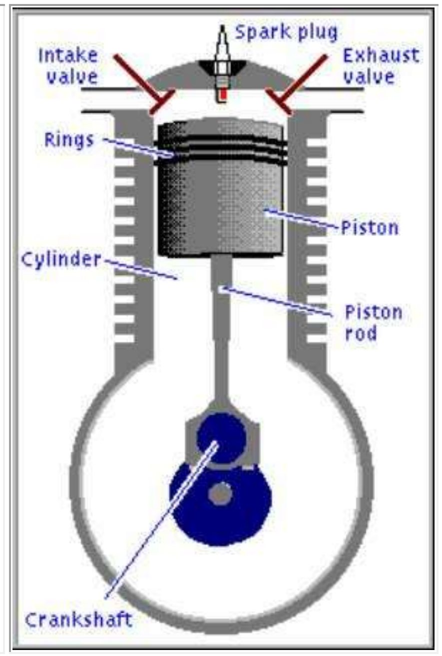
ADVANTAGES	DISADVANTAGES
It has no valves or camshaft mechanism, hence simplifying its mechanism and construction.	· The lack of lubrication system that protects the engine parts from wear. Accordingly, the 2-stroke engines have shorter life.
· For one complete revolution of the crankshaft, the engine executes one cycle—the 4-stroke executes 1 cycle per 2 crankshafts revolutions.	· They do not consume fuel efficiently.
· Less weight and easier to manufacture.	· They produce lots of pollution.
· High power to weight ratio	· Sometimes part of the fuel leaks to the exhaust with the exhaust gases.

In conclusion, based on the above advantages and disadvantages, the 2-stroke engines are supposed to operate in vehicles where the weight of the engine is required to be small, and the it is not used continuously for long times.

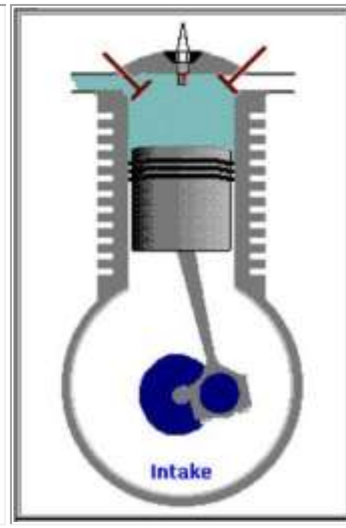
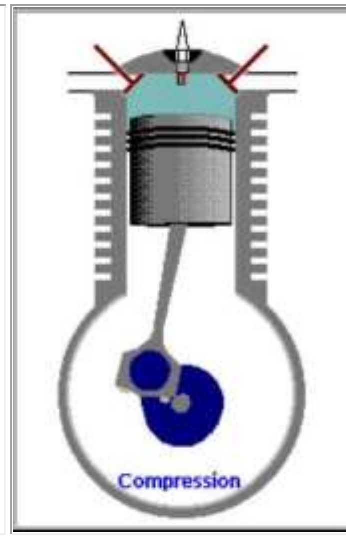
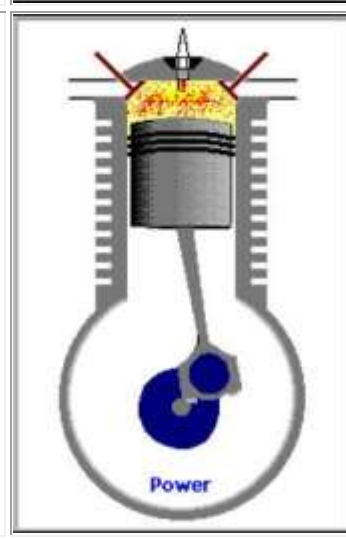
FOUR STROKE ENGINES:

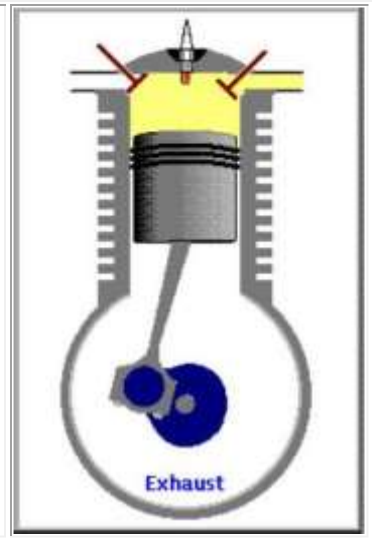
In 1867, Nikolaus August Otto, a German engineer, developed the four stroke "Otto" cycle, which is widely used in transportation even today. Otto developed the four stroke internal combustion engine when he was 34 years old. Actually most of today's gasoline cars use four stroke engines, which is a direct application for the thermodynamic cycle "Otto Cycle".

The cylinder of the four strokes engine differs from the two strokes engine. The major difference between both engines is the valves that are located on the top of the cylinder. These two valves open and close alternatively to allow either air/fuel mixture to enter or exhaust gases to come out. As it was previously mentioned, the motion of the two valves happen through the camshaft system. The spark plug is the one that ignites the compressed fuel-air mixture at a time when both valves are closed. Accordingly, the piston is pushed downward, transmitting power to the crankshaft. Power is then transferred to the wheel through other mechanisms. Figure 4



The four strokes can be identified as follows:

Suction (Intake) stroke: During this stroke, the piston starts its motion from the top downward of the cylinder. Synchronously, the intake valve is opened (based on the camshaft mechanism), allowing air/vaporized fuel mixture to enter to the combustion chamber.Figure 5a	
Compression stroke: In this one, both valves should be closed. The piston starts to move upward to compress the fuel, until it reaches the top dead center. By compressing the fuel, the fuel temperature and pressure increases.Figure 5b	
Power Stroke: As the piston reaches the top dead center, the spark plug ignites a spark, allowing the fuel to burn. The combustion yields a high power that is transmitted through the crankshaft mechanism. It should be noted that in order for the combustion energy to be consumed efficiently in moving the piston, both valves should be closed.Figure 5c	

Exhaust Stroke: After reaching to the maximum displacement of the piston, most of the energy liberated is transferred. Accordingly, the pistons starts it back upward motion to get rid of the exhaust gases that result from combustion. At that moment, the exhaust valve is opened to allow it to go outside the cylinder.Figure 5d	

It should be clear from the above argument that for one complete cycle to be done, the crankshaft has to finish two revolutions.

CYCLE CATEGORIZATION:

This is one of the important points to discuss, which is the thermodynamics of the combustion process. There are two main cycles based on which we can categorize internal combustion engines, which are: Otto cycle and Diesel cycle.

OTTO CYCLE:

Otto cycle is the typical cycle for most of the cars internal combustion engines, that work using gasoline as a fuel. Otto cycle is exactly the same one that was described for the four-stroke engine. It consists of the same four major steps: Intake, compression, ignition and exhaust.

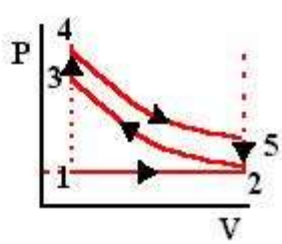


Figure 6
PV diagram for Otto cycle

On the PV-diagram,
1-2: Intake: suction stroke
2-3: Isentropic Compression stroke
3-4: Heat addition stroke

4-5: Exhaust stroke (Isentropic expansion)
5-2: Heat rejection
The distance between points 1-2 is the stroke of the engine. By dividing V2/V1, we get:

$$r \equiv \frac{V_2}{V_1}$$

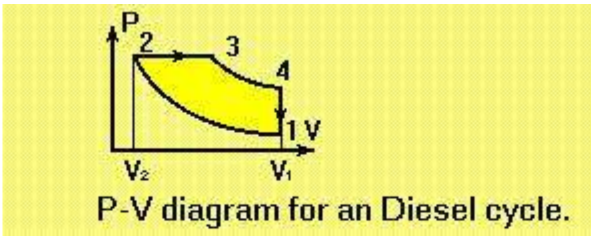
where r is called the compression ratio of the engine. The efficiency is taken to be:

$$\eta = 1 - r^{1-k}$$

$$K \equiv \frac{C_P}{C_V}$$

DIESEL CYCLE:

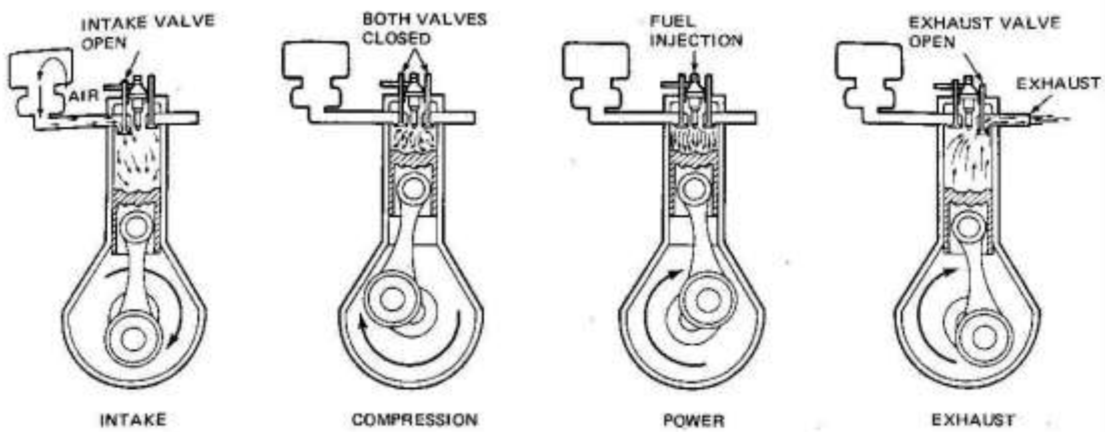
In the Diesel Cycle, named after Rudolf Christian Karl Diesel (1858-1913), only air is admitted in the intake stroke. The air is then adiabatically compressed, and fuel is injected into to the hot air in the form of many small drops (not a vapor). Each drop burns over a small time, giving an approximation of a isobaric explosion. The explosion pushes the cylinder outwards. The power stroke, valve exhaust, and exhaust stroke which follow are identical to those in the Otto Cycle.



P-V diagram for an Diesel cycle.

A - 1 to 2: Isentropic compression
B - 2 to 3: Reversible constant pressure heating
C - 3 to 4: Isentropic expansion
D - 4 to 1: Reversible constant volume cooling

In other words, the only difference between is the Otto engine and diesel engine is that the latter does not require a spark plug to ignite the fuel; the fuel here is ignited under the effect of increase in pressure and temperature. In Diesel engines, compression ratios are as high as 22.5 to 1, where for Otto engines it normally does not reach even one fifth that number.



The four cycles of the diesel engine are:

1 - The piston is moved away from the cylinder head by the crankshaft, drawing only air into the cylinder.

2 - The piston moves towards the cylinder head, compressing the air. At the end of the stroke vaporized fuel is injected into the cylinder and is ignited by the high temperature of the air.

3 - The piston is forced away from the cylinder head by the gas, expanding after the ignition of the fuel.

4 - The exhaust valve is opened and the piston moves towards the cylinder head, driving the exhaust gases from the cylinder.

CURRENT RESEARCH

Rotary Engine

In the 1950s the German engineer Felix Wankel developed an internal-combustion engine , in which the piston and cylinder were replaced by a three-cornered rotor turning in a roughly oval chamber. The fuel-air mixture is drawn in through an intake port and trapped between one face of the turning rotor and the wall of the oval chamber. The turning of the rotor compresses the mixture, which is ignited by a spark plug. The exhaust gases are then expelled through an exhaust port through the action of the turning rotor. The cycle takes place alternately at each face of the rotor, giving three power strokes for each turn of the rotor. Because of the Wankel engine's compact size and consequent lesser weight as compared with the piston engine, it appeared to be an important option for automobiles. In addition, its mechanical simplicity provided low manufacturing costs, its cooling requirements were low, and its low center of gravity made it safer to drive. A line of Wankel-engine cars was produced in Japan in the early 1970s, and several United States automobile manufacturers researched the idea as well. However, production of the Wankel engine was discontinued as a result of its poor fuel economy and its high pollutant emissions.

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CONCLUSION:

Internal combustion engines are among the most important engineering applications. The theory of application either depends on Diesel or Otto cycles. They are categorized either according to the operating cycle, or due to the mechanism of working.

Each type of engines has some advantages over the other one. Thus, the selection of the appropriate engine requires determining the conditions of application.