IQRA NATIONAL UNIVERSITY, PESHAWAR

Department of Electrical Engineering

Course Title: Thermodynamics **Module: 02**

Instructor: Dr. Mujtaba **Total Marks: 50**

STUDENT DETAILS

Name: Muhammad Faizan **Student ID: 16046**

Date: 22/02/2020

Q1. (a) **State** the following along with their mathematical expressions: Marks 04+06
i. The ideal gas law
ii. Dalton's law of partial pressure

(b) **Explain** the Carnot cycle.

CLO 2

Q2. (a) You need to buy a refrigerator for your home. **Outline** the key factors that you will consider while buying the refrigerator. Marks 05+08

(b) **Explain** vapour absorption refrigeration system.

CLO 3

Q3. **Distinguish** between water tube & fire tube boilers. Marks 06

CLO 3

Q4. State the meaning of the word "stroke" & **describe** the working of a 04 stroke engine. Marks 12

CLO 3

Q5. (a) **Outline** the differences between a petrol engine & a diesel engine. Marks 04+05

(b) Several provincial governments in Pakistan have banned the use of 02 stroke engines in auto rickshaws. **Identify** the causes behind this decision.

CLO 3

Q1:

a) State the following along with their mathematical expressions;

- **i) The ideal gas law**
- **ii) Dalton's law of partial pressure**

Ans: a) Ideal Gas Law

The ideal gas law, also called the general gas equation, is the equation of state of a hypothetical ideal gas. It is a good approximation of the behaviour of many gases under many conditions, The ideal gas law is often written in an empirical form:

$PV = nRT$

where P,V and T and are the pressure, volume and temperature; n is the amount of substance; and R is the ideal gas constant. It is the same for all gases.

The Ideal Gas Law is simply the combination of all Simple Gas Laws (Boyle's Law, Charles' Law, and Avogadro's Law).

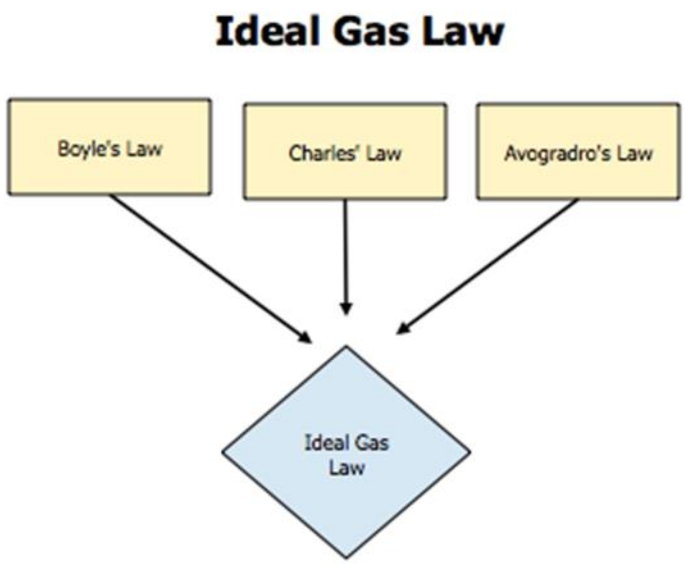


Figure: Ideal gas law

b) Dalton's law of partial pressure

Dalton's law of partial pressures states that the total pressure of a mixture of gases is the sum of the partial pressures of its components:

$P_{Total} = P_{gas1} + P_{gas2} + P_{gas3} \ldots$

Dalton's law can also be expressed using the mole fraction of a gas, x:

Pgas1 = x1 Ptotal

b) Explain the Carnot Cycle

Ans: Carnot Cycle

A Carnot cycle is defined as an ideal reversible closed thermodynamic cycle in which there are four successive operations involved and they are isothermal expansion, adiabatic expansion, isothermal compression, and adiabatic compression. During these operations, the expansion and compression of substance can be done up to desired point and back to initial state.

Following are the four processes of Carnot cycle;

• In (a), the process is reversible isothermal gas expansion. In this process, the amount of heat absorbed by the ideal gas is qin from the heat source which is at a temperature of Th. The gas expands and does work on the surroundings.

• In (b), the process is reversible adiabatic gas expansion. Here, the system is thermally insulated and the gas continues to expand and work is done on the surroundings. Now the temperature is lower, Tl.

• In (c), the process is reversible isothermal gas compression process. Here, the heat loss, qout occurs when the surroundings do the work at temperature Tl.

• In (d), the process is reversible adiabatic gas compression. Again the system is thermally insulated. The temperature again rise back to Th as the surrounding continue to do their work on the gas.

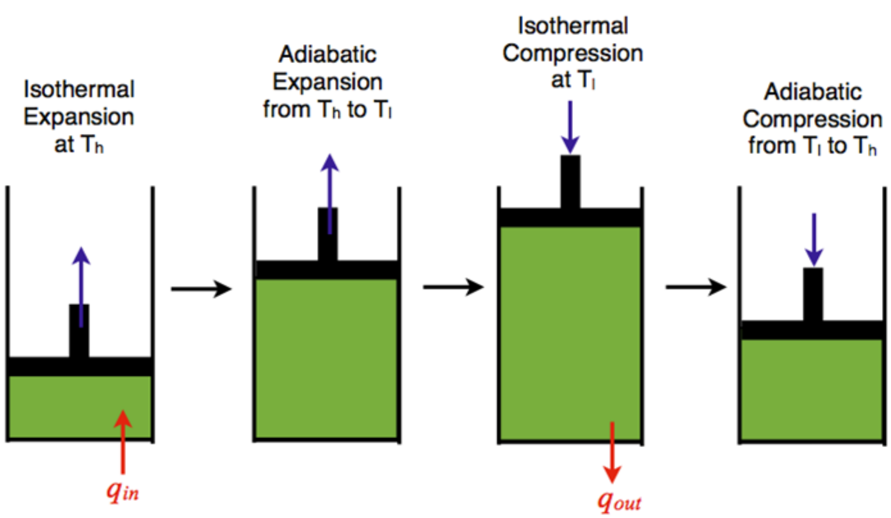


Figure: An ideal gas-piston model of the Carnot cycle

Steps involved in a Carnot Cycle

For an ideal gas operating inside a Carnot cycle, the following are the steps involved:

Step 1: Isothermal expansion: The gas is taken from P1, V1, T1 to P2, V2, T2. Heat Q1 is absorbed from the reservoir at temperature T1. Since the expansion is isothermal, the total change in internal energy is zero and the heat absorbed by the gas is equal to the work done by the gas on the environment, which is given as:

$W1\rightarrow2=Q1=\mu\times R\times T1\times \ln v2/v1$

Step 2: Adiabatic expansion: The gas expands adiabatically from P2, V2, T1 to P3, V3, T2.

Here work done by the gas is given by:

$W2\rightarrow3=\mu R/\gamma-1(T1-T2)$

Step 3: Isothermal compression: The gas is compressed isothermally from the state (P3, V3, T2) to (P4, V4, T2).

Here, the work done on the gas by the environment is given by:

$W3\rightarrow4=\mu RT2\ln v3/v4$

Step 4: Adiabatic compression: The gas is compressed adiabatically from the state (P4, V4, T2) to (P1, V1, T1).

Here, the work done on the gas by the environment is given by:

$W4\rightarrow1=\mu R/\gamma-1(T1-T2)$

Q2:

a) **You need to buy a refrigerator for your home. Outline the key factors that you will consider while buying the refrigerator.**

Ans: Four things to consider when buying a refrigerator

Buying a new refrigerator is a big decision. Not only is the refrigerator a centrepiece among your collection of kitchen appliances, it’s a gathering place for preparing family meals. You rely on it to keep your food fresh. Besides, the moment you walk into a store or begin your online shopping, you will encounter seemingly endless decision points – from sizes and configurations to features and more. But the time is now. Follow these easy tips, and you’ll be well on your way to big savings.

i) Look for the ENERGY STAR

ENERGY STAR is the simple choice for saving energy, saving money and helping to protect the climate. After heating, cooling, and hot water, the refrigerator is probably the next largest energy user in your home. Thanks to recent improvements in insulation and compressors, today's refrigerators use much less energy than older models. In fact, a 15 year old refrigerator uses 33% more energy as a new ENERGY STAR certified model.

ii) Consider a Refrigerator with a Top-Mounted Freezer

Refrigerators are sold in many configurations including top freezer, bottom freezer, and side-by-side. Your new refrigerator doesn't have to be the same configuration you had before, so long as you account for proper sizing as discussed below. A top-freezer refrigerator that has earned the ENERGY STAR uses less energy than a 60-watt light bulb. Top freezer models tend to use the least energy of all refrigerator configurations and are affordably priced. On average, an ENERGY STAR certified top freezer refrigerator costs about $45 a year to run, while a side-by-side costs about $77, and a bottom freezer costs about $70.

iii) Purchase an Appropriately Sized Refrigerator

Generally, the larger the refrigerator, the greater the energy consumption. The most energy-efficient models are typically 16-20 cubic feet. When you replace an old refrigerator with a new one, do not keep the old refrigerator for extra cold storage. If your refrigeration needs absolutely cannot be met by a single refrigerator, make sure that the second refrigerator or freezer is an energy efficient model that is no bigger than what you need. Be certain to recycle your existing second refrigerator from your garage or basement.

iv) Consider the Features that are Most Important to You

Which features do you need in your new fridge? Think about whether you'll want an icemaker, through-the-door ice, or hot water, so that you only pay for what you use – both in the initial purchase price and over the lifetime of the product.

b) Explain vapor absorption refrigeration system?

Ans: Vapour absorption refrigeration system

The power utilized in vapour compression system is high grade energy i.e., electric power for running the compressor motor. In absorption refrigeration system, however, heat is directly utilized as source of energy. Of course, it may be preferable to utilize heat as such as it avoids undergoing through the various energy transformations required in the generation of electrical energy from heat energy.

It may be recalled that in the compression system the vapour was compressed by undergoing a great change in volume during the compression process. Accordingly the major part of the power was consumed in the process. If means were available for rising this pressure of the refrigerant without appreciably altering its volume, the work requirements will be enormously reduced (by about 95% or so).

This may possibly be done by dissolving the refrigerant in some absorbent and supplying the heat to the solution for compression purposes. The absorption cycle achieves this objective by placing the refrigerant in solution before the so called compression process and by removing from the solution immediately after the process. The absorption of the vapour is governed by Raoult's law.

The basic difference between vapour compression and vapour absorption cycles will thus be to replace the compressor of the vapour compression cycle by a set of equipment which fulfils the objective discussed above. The other important element i.e., condenser, expansion device and evaporator will exist in both systems.

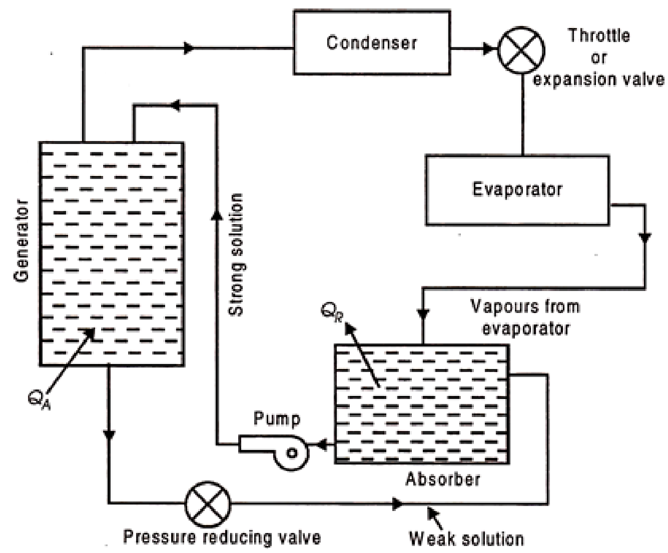


Figure: Vapor absorption refrigeration system

Practical Absorption Refrigeration Cycle:

The replacement of the compressor by the simple arrangement of Fig. 36.33 is not very economical in practice. In order to make improvements certain additional auxiliary items are provided in the system. They include analyser, a rectifier, and two heat exchangers. The practical absorption cycles as developed after incorporating these auxiliaries is shown in Fig 2.2.

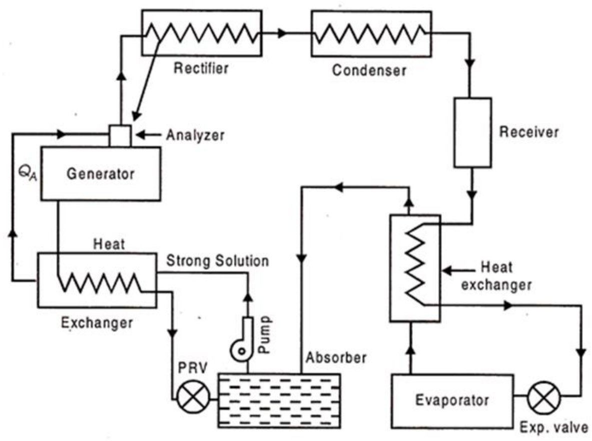


Figure: Practical absorption refrigeration system

(a) Analyzer: The ammonia vapours leaving the generator may contain certain moisture, and therefore it should be freed from any trace of water vapour before passing on to the condenser and then to the expansion valve, otherwise the water vapour is likely to freeze in the small valve passage and choke the flow.

The function of the analyzer is to remove the moisture as far as possible. It is an open types of cooler and forms an integral part of the generator, mounted on its top. Both the strong aqua-ammonia solution from the absorber and the condensate removed in rectifier are introduced from the top and flow downwards.

The hot rising vapour of ammonia therefore comes in contact with the same and gets cooled. Thus most of the water vapour is condensed and drips back into the generator. This helps in salvaging a certain portion of heat in outgoing vapour which would otherwise have been rejected out through the condenser.

(b) Rectifier: It is a closed type of cooler and is actually a miniature condenser where any traces of water vapour left in the ammonia vapour, are removed by condensation .The cooling is achieved by circulating water as is done in an ordinary condenser. The condensed aqua is drained back to the generator through the analyzer.

(c) Heat Exchangers: Two heat exchangers are provided to internally exchange heat from the higher temperature fluid to the lower temperature fluid so that one is cooled and the other is heated.

One heat exchanger is provided between liquid receiver and evaporator so that the liquid is sub-cooled and vapour is heated up. Another heat exchanger is located between generator and absorber so that the strong aqua is heated up before going on to the analyzer and weak aqua is cooled before entering the absorber.

Q3: Distinguish between fire tube and water tube boilers.

Ans: Fire tube boilers

In a fire tube or shell boiler, the hot combustion gases produced by the burner are passed through small tubes arranged in a pressurised cylindrical drum and surrounded by water. Heat energy is transferred to the water which is heated up until it becomes steam.

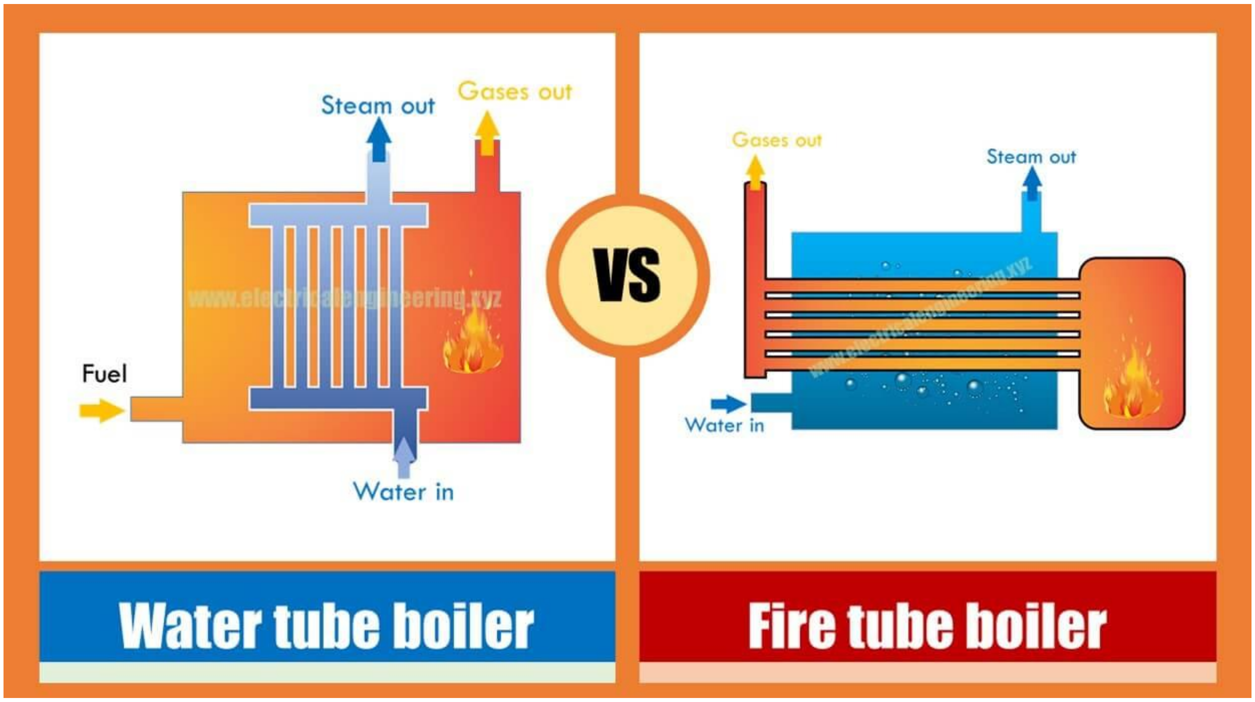
Water tube boilers

Industrial water-tube boilers work in the opposite way: water is circulated inside the boiler tubes and the tubes are surrounded by hot gases.

Differences between fire tube and water tube boilers

Fire tube boiler	Water tube boiler
In Fire-tube boilers hot flue gases pass through tubes and water surrounds them.	In Water-tube boilers water passes through tubes and hot flue gasses surround them.
These are operated at low pressures up to 20 bar.	The working pressure is high enough, up to 250 bar in super critical boilers.
The rate of steam generation and quality of steam are very low, therefore, not suitable for power generation.	The rate of steam generation and quality of steam are better and suitable for power generation.
Load fluctuations cannot be handled.	Load fluctuations can be easily handled.
It requires more floor area for a given output.	It requires less floor area for a given output.
These are bulky and difficult to transport.	These are light in weight; hence transportation is not a problem.
Overall efficiency is up to 75%.	Overall efficiency with an economizer is up to 90%.
Water doesn’t circulate in a definite direction.	Direction of water circulated is well defined.
The drum size is large, and damage caused by bursting is large.	If any water tube is damaged, it can be easily replaced or repaired.
Simple in design, easy to erect and low maintenance cost.	Complex, design, difficult to erect and high maintenance cost.
Even less skill operators are sufficient for efficient operation.	Skilled operators are required for operation.
The treatment of feed water is not very essential, as overheating due to scale formation cannot burst thick shell.	Treatment of feed water is very essential as small scale deposits inside the tubes can cause overheating and bursting.

Used in process industry.	Used in large power plants.
The maintenance of this boiler is costly. It requires regular inspection.	They are easy to maintain as they are externally fired.
They are difficult to repair and cleaning as they are internally fired.	They are easy to repair and clean as they are externally fired.
Ex: Cornish Boiler, Lancashire Boiler.	Ex: Babcock and Wilcox Boiler.



Q4: State the meaning of the word "stroke" and describe the working of a 04-stroke engine.

Ans: Stroke

In the context of an internal combustion engine, the term stroke has the following related meanings;

"A phase of the engine's cycle (e.g. compression stroke, exhaust stroke), during which the piston travels from top to bottom or vice versa".

"The type of power cycle used by a piston engine (e.g. two-stroke engine, four-stroke engine)".

"Stroke length", the distance travelled by the piston in each cycle. The stroke length along with bore diameter, determines the engine's displacement.

Working of a 04-stroke engine

A four-stroke cycle engine is an internal combustion engine that utilizes four distinct piston strokes (intake, compression, power, and exhaust) to complete one operating cycle. The piston make two complete passes in the cylinder to complete one operating cycle. An operating cycle requires two revolutions (720°) of the crankshaft. The four-stroke cycle engine is the most common type of small engine. A four-stroke cycle engine completes five Strokes in one operating cycle, including intake, compression, ignition, power, and exhaust Strokes.

1. **Intake Stroke**

The intake event is when the air-fuel mixture is introduced to fill the combustion chamber. The intake event occurs when the piston moves from TDC to BDC and the intake valve is open. The movement of the piston toward BDC creates a low pressure in the cylinder. Ambient atmospheric pressure forces the air-fuel mixture through the open intake valve into the cylinder to fill the low pressure area created by the piston movement. The cylinder continues to fill slightly past BDC as the air-fuel mixture continues to flow by its own inertia while the piston begins to change direction. The intake valve remains open a few degrees of crankshaft rotation after BDC. Depending on engine design. The intake valve then closes and the air-fuel mixture is sealed inside the cylinder.

2. **Compression Stroke**

The compression stroke is when the trapped air-fuel mixture is compressed inside the cylinder. The combustion chamber is sealed to form the charge. The charge is the volume of compressed air-fuel mixture trapped inside the combustion chamber ready for ignition. Compressing the air-fuel mixture allows more energy to be released when the charge is ignited. Intake and exhaust valves must be closed to ensure that the cylinder is sealed to provide compression. Compression is the process of reducing or squeezing a charge from a large volume to a smaller volume in the combustion chamber. The flywheel helps to maintain the momentum necessary to compress the charge.

When the piston of an engine compresses the charge, an increase in compressive force supplied by work being done by the piston causes heat to be generated. The compression and heating of the air-fuel vapor in the charge results in an increase in charge temperature and an increase in fuel vaporization. The increase in charge temperature occurs uniformly throughout the combustion chamber to produce faster combustion (fuel oxidation) after ignition.

The increase in fuel vaporization occurs as small droplets of fuel become vaporized more completely from the heat generated. The increased droplet surface area exposed to the ignition flame allows more complete burning of the charge in the combustion chamber. Only gasoline vapor ignites. An increase in droplet surface area allows gasoline to release more vapor rather than remaining a liquid.

The more the charge vapor molecules are compressed, the more energy obtained from the combustion process. The energy needed to compress the charge is substantially less than the gain in force produced during the combustion process. For example, in a typical small engine, energy required to compress the charge is only one-fourth the amount of energy produced during combustion.

The compression ratio of an engine is a comparison of the volume of the combustion chamber with the piston at BDC to the volume of the combustion chamber with the piston at TDC. This area, combined with the design and style of combustion chamber, determines the compression ratio. Gasoline engines commonly have a compression ratio ranging from 6:1 - 10:1. The higher the compression ratio, the more fuel-efficient the engine. A higher compression ratio normally provides a substantial gain in combustion pressure or force on the piston. However, higher compression ratios increase operator effort required to start the engine. Some small engines feature a system to relieve pressure during the compression stroke to reduce operator effort required when starting the engine

3. Ignition Event

The ignition (combustion) event occurs when the charge is ignited and rapidly oxidized through a chemical reaction to release heat energy. Combustion is the rapid, oxidizing chemical reaction in which a fuel chemically combines with oxygen in the atmosphere and releases energy in the form of heat.

Proper combustion involves a short but finite time to spread a flame throughout the combustion chamber. The spark at the spark plug initiates combustion at approximately 20° of crankshaft rotation before TDC (BTDC). The atmospheric oxygen and fuel vapor are consumed by a progressing flame front. A flame front is the boundary wall that separates the charge from the combustion by-products. The flame front progresses across the combustion chamber until the entire charge has burned.

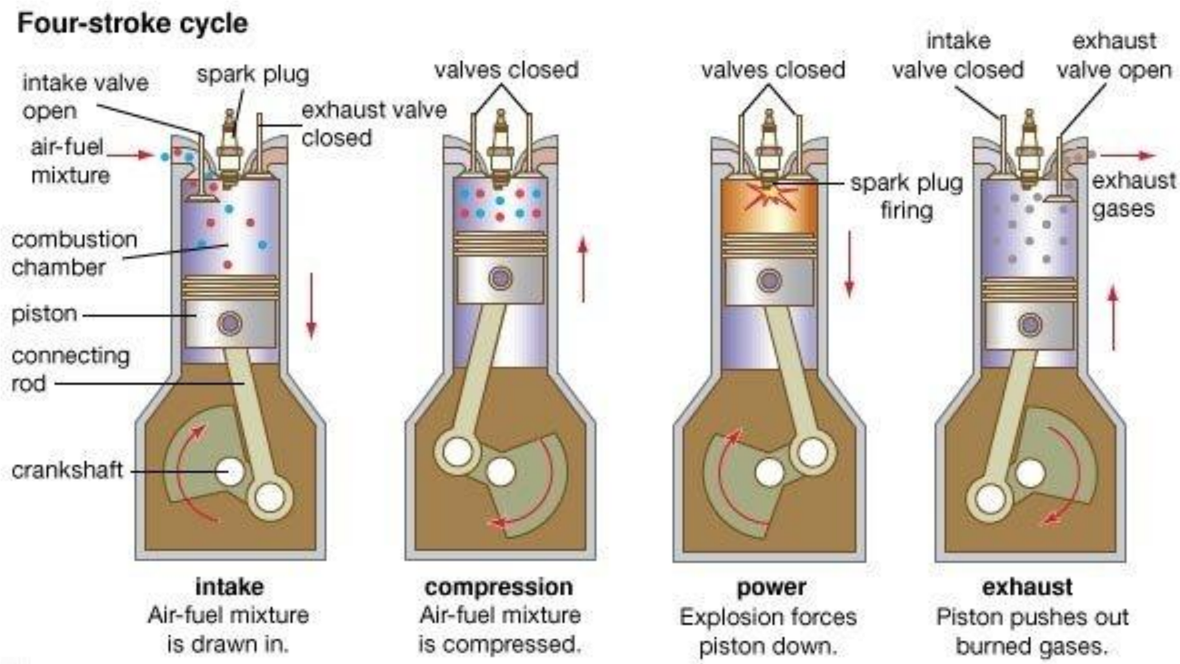
4. Power Stroke

The power stroke is an engine operation Stroke in which hot expanding gases force the piston head away from the cylinder head. Piston force and subsequent motion are transferred through the connecting rod to apply torque to the crankshaft. The torque applied initiates crankshaft rotation. The amount of torque produced is determined by the pressure on the piston, the size of the piston, and the throw of the engine. During the power Stroke, both valves are closed.

5. Exhaust Stroke

The exhaust stroke occurs when spent gases are expelled from the combustion chamber and released to the atmosphere. The exhaust stroke is the final stroke and occurs when the exhaust valve is open and the intake valve is closed. Piston movement evacuates exhaust gases to the atmosphere.

As the piston reaches BDC during the power stroke combustion is complete and the cylinder is filled with exhaust gases. The exhaust valve opens, and inertia of the flywheel and other moving parts push the piston back to TDC, forcing the exhaust gases out through the open exhaust valve. At the end of the exhaust stroke, the piston is at TDC and one operating cycle has been completed.



Q5:

a) Outline the differences between petrol and diesel engine?

Ans: Petrol Engine

An internal combustion engine that works on petrol fuel is called a petrol engine. It works on the principle of the Otto cycle. In the petrol engine, a carburetor is used to make an air petrol mixture that will enter the cylinder. The Flashpoint (−43 °C (−45 °F)) of petrol is low and due to this, it can ignite at low temperature which results in a low compression ratio. The power obtained in the petrol engine is less as compared with the diesel engine.

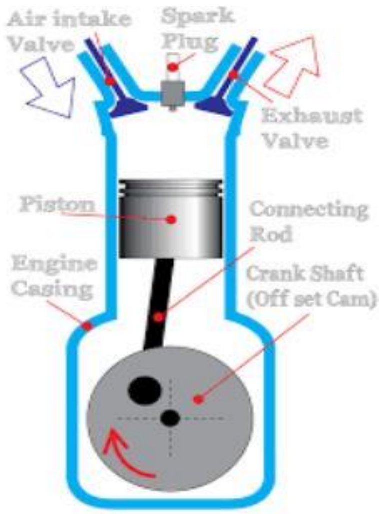
Diesel Engine

An internal combustion engine that works on diesel fuel is called diesel engine. It works on the principle of the Diesel cycle. In this engine, we have a fuel injector for the injection of diesel into the cylinder. The air-fuel mixture is not prepared in diesel engines, but the air and fuel enter into the cylinder separately.

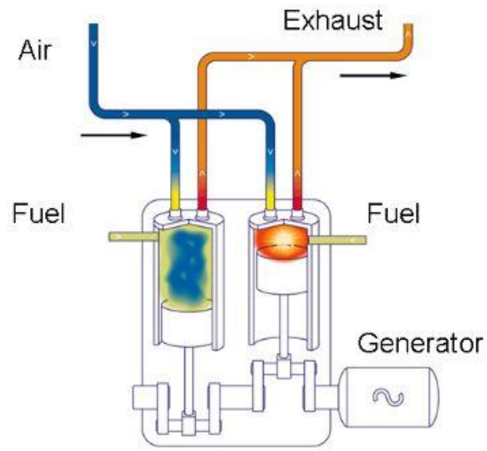
Since the flash point (>52 °C (126 °F)) of the diesel engine is high and as a result of that, it has a high compression ratio. No spark plug is used in this for the combustion of diesel. The heat of the air is used to ignite the diesel sprayed in the form of mist by the fuel injector. The power produced in a diesel engine is very high as compared with the petrol engine.

Differences between petrol and diesel engine

Petrol engine	**Diesel engine**
The petrol engine works on the Otto cycle i.e. on constant volume.	The diesel engine works on the diesel cycle i.e. on constant pressure.
The air and petrol are mixed in the carburetor before they enter into the cylinder.	The fuel is fed into the cylinder by a fuel injector and is mixed with hot compressed air inside the cylinder.
The petrol engine compresses a mixture of air and petrol which is ignited by an electric spark.	The diesel engine compresses only a charge of air and ignition is done by the heat of compression.
The compression ratio is low. 10:1 to 14:1. (air: fuel)	The compression ratio is higher in a diesel engine. 18:1 to 23:1.
Less power is produced due to the lower compression ratio.	Due to the higher compression ratio more power is produced.
The petrol engine is fitted with a spark plug	It is fitted with a fuel injector.
Burns fuel that has high volatility.	Burns fuel that has low volatility.
They are used in light vehicles which requires less power. Eg: car, jeep, motorcycle, scooters, etc.	They are used in heavy vehicles that require high power. Eg: bushes, trucks, locomotive, etc.
Fuel consumption in a petrol engine is high.	Fuel consumption in a diesel engine is less.
Lighter in weight.	Heavier in weight.
The petrol engine requires frequent overhauling.	Overhauling of a diesel engine is done after a long time.
Lesser starting problem.	Greater starting problem.
Lower initial cost.	Higher initial cost.
Lower maintenance cost.	Higher maintenance cost.



Petrol Engine



Diesel Engine

b) Several provincial governments in Pakistan have banned the use of 02 stroke engines in auto rikshaws. Identify the causes of this decision.

Ans: The main causes of the ban on the use of 02 stroke engines in auto rikshaws by the provincial government of Pakistan are;

- **More pollution:** 2 stroke engine produces a lot of pollution. The combustion of oil added in the mixture creates a lot of smoke which leads to air pollution.

The motorcycles and rickshaws, due to being equipped with two-stroke engines, are the most inefficient vehicles in complete burning of fuel and thus contribute most to emission of air pollutants in the environment. The major pollutants from two-stroke engines are Carbon Monoxide (CO), Nitrogen Oxides (NOx), Hydrocarbons (HC) and Particulate Matter (PM). Their presence in the environment causes several respiratory diseases and other illnesses. For example, CO and NOx are notorious irritants of respiratory system and have potential suffocating action. PM causes premature death, and illness. Its presence is accompanied by increased hospital admissions for asthma and other bronchial conditions such as bronchitis, etc.

None of the locally assembled rickshaws meets standards fixed by Pakistan Standards Quality Control Authority for smoke emission.

- **Oil addition could be expensive:** Two-stroke engines require a mix of oil in with the air-fuel mixture to lubricate the crankshaft, connecting rod and cylinder walls. These oils may empty your pockets.
- **Less fuel efficiency:** For every alternate power stroke, fuel gets consumed every alternate stroke. This makes the engine less fuel efficient although it results in uniform power delivery.

- **Wastage of fuel:** Sometimes the fresh charge which is going to undergo combustion gets out along with the exhaust gases. This leads to wastage of fuel & also power delivery of the engine gets effected.
- **Improper combustion:** The exhaust gases often get trapped inside the combustion chamber. This makes the fresh charge impure. Therefore, maximum power doesn’t get delivered because of improper incomplete combustion.
- High vibration and noisy operation.
- More wear and fragile than 4 stroke engines. Short life span.