THERMODYNAMICS-I

LABORATORY MANUAL

DEPARTMENT OF MECHANICAL ENGINEERING (NEW CAMPUS)

UNIVERSITY OF ENGINEERING & TECHNOLOGY LAHORE, PAKISTAN

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Preface

In most of the engineering institutions, the laboratory course forms an integral form of the basic course in Thermodynamics at undergraduate level. The experiments to be performed in a laboratory should ideally be designed in such a way as to reinforce the understanding of the basic principles as well as help the students to visualize the various phenomenon encountered in different applications.

The objective of this manual is to familiarize the students with practical skills, measurement techniques and interpretation of results. It is intended to make this manual self-contained in all respects, so that it can be used as a laboratory manual. In all the experiments, the relevant theory and general guidelines for the procedure to be followed have been given. Tabular sheets for entering the observations have also been provided in each experiment while graph sheets have been included wherever necessary.

It is suggested that the students should complete the computations, in the laboratory itself. However the students are advised to refer to the relevant text before interpreting the results and writing a permanent discussion. The questions provided at the end of each experiment will reinforce the students understanding of the subject and also help them to prepare for viva-voce exams.

General Instructions to Students

- The purpose of this laboratory is to reinforce and enhance your understanding of the fundamentals of Fluid mechanics and Hydraulic machines. The experiments here are designed to demonstrate the applications of the basic fluid mechanics principles and to provide a more intuitive and physical understanding of the theory. The main objective is to introduce a variety of classical experimental and diagnostic techniques, and the principles behind these techniques. This laboratory exercise also provides practice in making engineering judgments, estimates and assessing the reliability of your measurements, skills which are very important in all engineering disciplines.
- Read the lab manual and any background material needed before you come to the lab. You must be prepared for your experiments before coming to the lab. In many cases you may have to go back to your fluid mechanics textbooks to review the principles dealt with in the experiment.
- Actively participate in class and don't hesitate to ask questions. Utilize the teaching assistants. You should be well prepared before coming to the laboratory, unannounced questions may be asked at any time during the lab.
- Carelessness in personal conduct or in handling equipment may result in serious injury to the individual or the equipment. Do not run near moving machinery. Always be on the alert for strange sounds. Guard against entangling clothes in moving parts of machinery.
- Students must follow the proper dress code inside the laboratory. To protect clothing from dirt, wear a lab apron. Long hair should be tied back.
- Calculator, graph sheets and drawing accessories are mandatory.
- In performing the experiments, proceed carefully to minimize any water spills, especially on the electric circuits and wire.
- Make your workplace clean before leaving the laboratory. Maintain silence, order and discipline inside the lab.
- Cell phones are not allowed inside the laboratory.
- Any injury no matter how small must be reported to the instructor immediately.
- Wish you a nice experience in this lab

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LAB SESSION NO: 01

THERMODYNAMICS FOR TECHNOLOGIST

NOZZLE DISTRIBUTION UNIT

OBJECTIVE NO: 1

Demonstrate that Pressure is an intensive property

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Figure 1: Nozzle Distribution Unit

1. OBJECTIVE

Demonstrate that Pressure is an intensive property.

1.1 APPARATUS:

Nozzle Distribution unit

1.2 SCHEMATIC DIAGRAM:

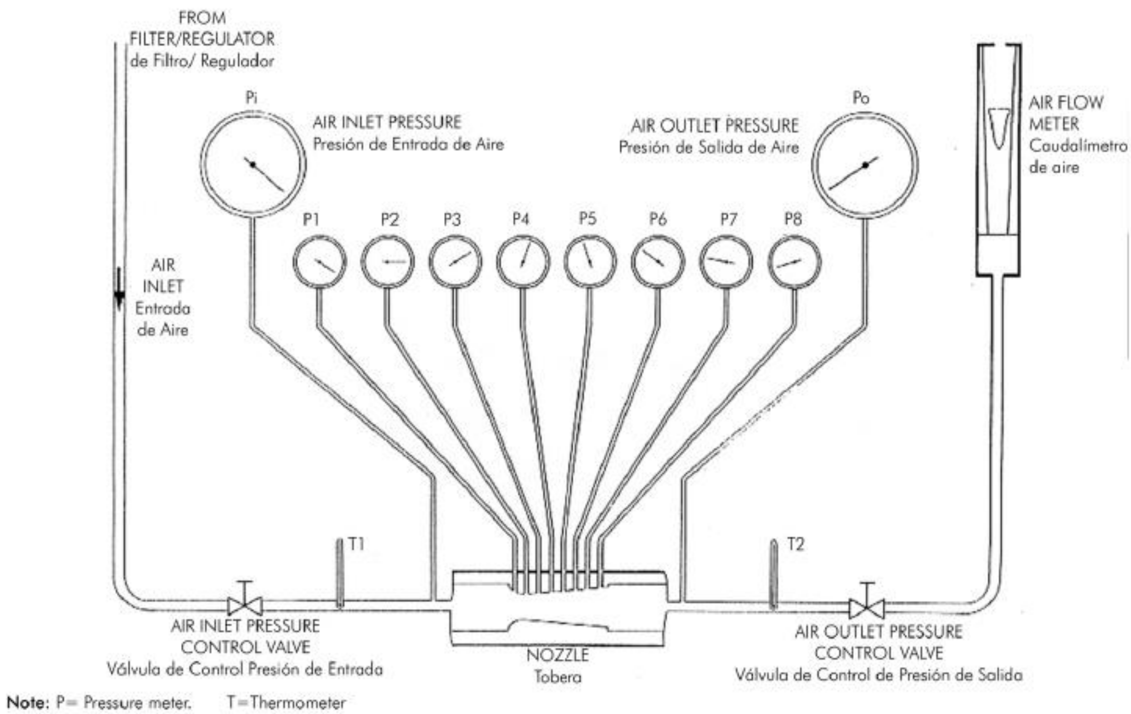


Figure 2: Schematic diagram of nozzle distribution unit

1.3 APPARATUS DESCRIPTION:

This unit has been specifically designed to demonstrate the phenomena associated to fluxes through nozzles and to allow the quick investigation of the pressure distribution in it. Besides, it allows the investigation of the mass flow rate through convergent-divergent and convergent nozzles. Since the unit works with ambient temperature air, it is stabilized quickly and its energy consumption is only the necessary one to impulse a relatively small compressor. Compressed air at a 7 to 9 bars pressure, supplied from an external service. It passes through the filter/regulator, located on the back part of the unit. In the unit, the air passes through a control valve, which allows an accurate control of the pressure at the inlet of the nozzle. The pressure and inlet temperature are measured and then the air is expanded through the nozzle chosen. When discharging from the nozzle, the pressure is controlled by other valve, and the air goes finally through a flow meter to the atmosphere. The nozzles have been made of brass, have been mechanized accurately and several pressure tapings are available, being each one connected to its own manometer to indicate the static pressure. Bench-top unit. Anodized aluminium structure and panels in painted steel. Diagram in the front panel with similar distribution to the elements in the real unit. Nozzles: Convergent type (conical), with 6 pressure tapings. Convergent- divergent type, with 5 pressure tapings, for a design pressure ratio of 0.25. Convergent- divergent, with 8 pressure tapings, for a design pressure ratio of 0.1. Nozzles can be changed quickly and easily. 2 Pressure meters (manometers), 100 mm. diameter, to measure air inlet and outlet pressures (range: 0 to 10 bar). 8 Pressure meters (manometers), 60 mm. diameter, to determine the pressure at the nozzle tapings (range: -1 to 8 bars). Variable area type flow meter to indicate air flow at standard conditions (p= 1.2kg/m^3). (Correction factors for other pressures and temperatures are provided). Range 0 to 9 g/s. 2 Glass temperature meters, to indicate air temperature before and after nozzle (range: 0 to 50ºC).Valves to give a fine control of air inlet pressure and outlet pressure. Air filter and pressure regulator to provide constant pressure, clean and water free air to the unit. This is to be installed by the customer in the pipe between his compressed air service and the unit, and must be drained regularly. Works a ambient temperature- stabilizes immediately. Allows students to make a comprehensive investigation in a normal laboratory period. Gives students an opportunity to calibrate equipment. Cables and accessories, for normal operation.

1.2 THEORY:

Pressure is defined as a normal force exerted by a fluid per unit area. We speak of pressure only when we deal with a gas or a liquid. The counterpart of pressure in solids is normal stress. Since pressure is defined as force per unit area, it has the unit of newton per square meter (N/m^2), which is called a Pascal (1 Pa =1 N/m^2). The pressure unit Pascal is too small for pressures encountered in practice. Therefore, its multiples kilopascal (1 kPa = 10^3 Pa) and mega Pascal (1 MPa = 10^6 Pa) are commonly used. Three other pressure units commonly used in practice, especially in Europe, are bar, standard atmosphere, and kilogram-force per square centimetre:

1 bar= 10^5 pa=0.1 MPa=100kPa : 1 atm= 101,325 pa=101.325kPa=1.01325bars

1kgf/cm^3 =9.807N/cm^3 =9.807 ×10^4N/m^2=9.807 × 10^4Pa=0.9807bar=0.9679atm

Absolute pressure: The actual pressure at a given position. It is measured relative to absolute vacuum (i.e., absolute zero pressure).

Gage pressure: The difference between the absolute pressure and the local atmospheric pressure. Most pressure-measuring devices are calibrated to read zero in the atmosphere, and so they indicate gage pressure.

Vacuum pressures: Pressures below atmospheric pressure.

$$P_{gage} = P_{abs} - P_{atm}$$

$$P_{vac} = P_{atm} - P_{abs}$$

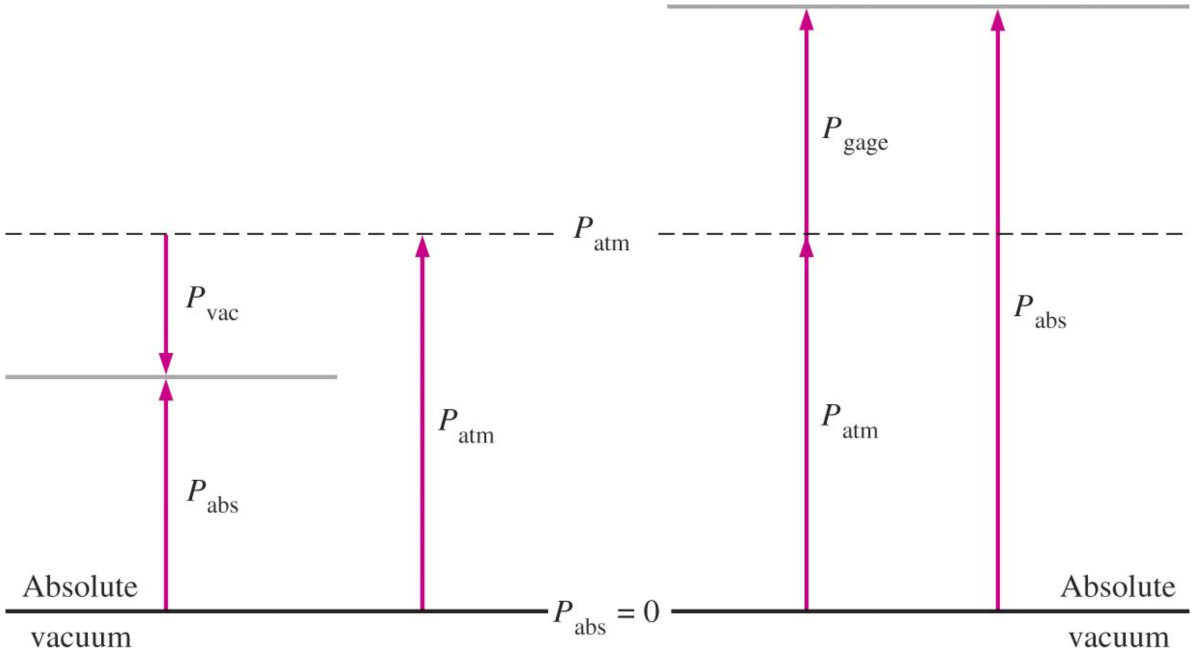


Figure 3: Variation of various pressures in reference to absolute pressure

Variation of Pressure with Depth:

- Pressure in a fluid at rest does not change in the horizontal direction. This can be shown easily by considering a thin horizontal layer of fluid and doing a force balance in any horizontal direction. However, this is not the case in the vertical direction in a gravity field.
- Pressure in a fluid increases with depth because more fluid rests on deeper layers, and the effect of this "extra weight" on a deeper layer is balanced by an increase in pressure.

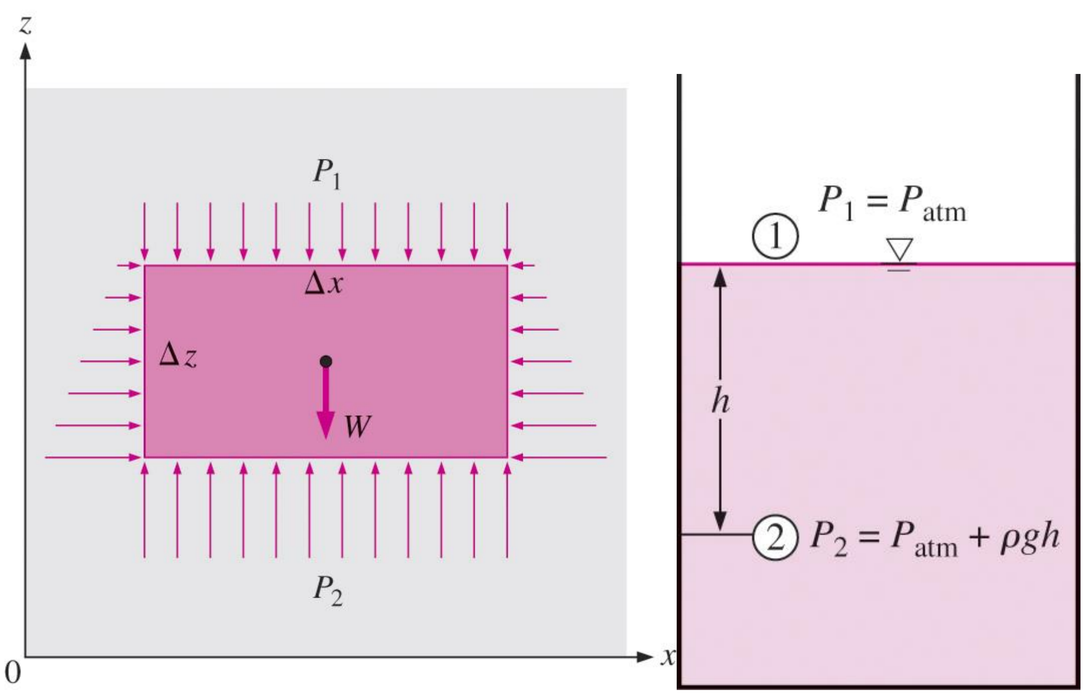


Figure 4: The pressure of a fluid at rest increases with depth (as a result of added weight).

The pressure is the same at all points on a horizontal plane in a given fluid regardless of geometry, provided that the points are interconnected by the same fluid.

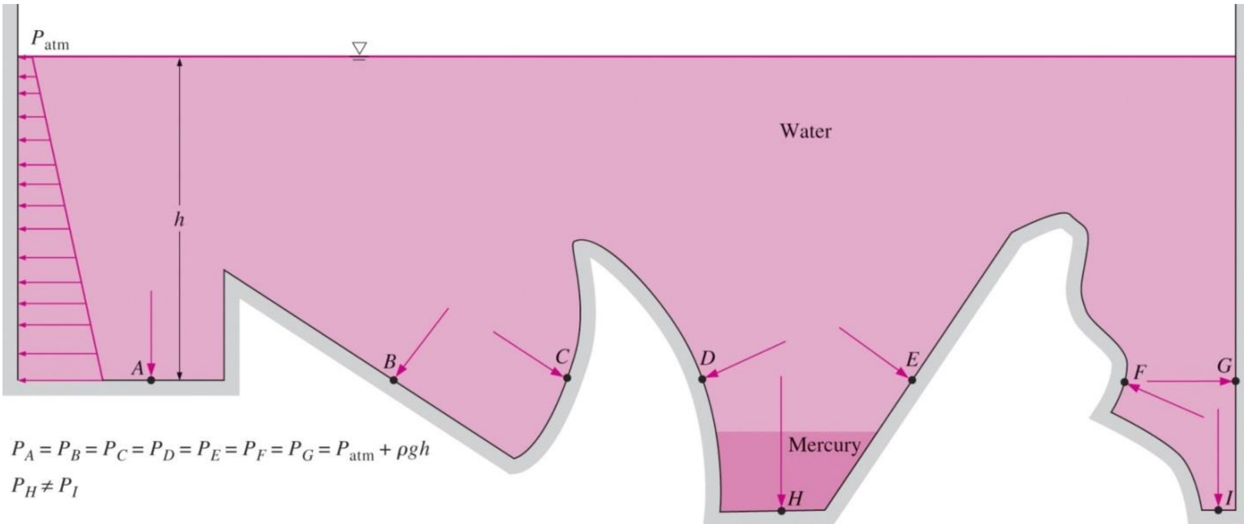


Figure 5: Variation of pressure across an irregular surface

Pascal's law: The pressure applied to a confined fluid increases the pressure throughout by the same amount.

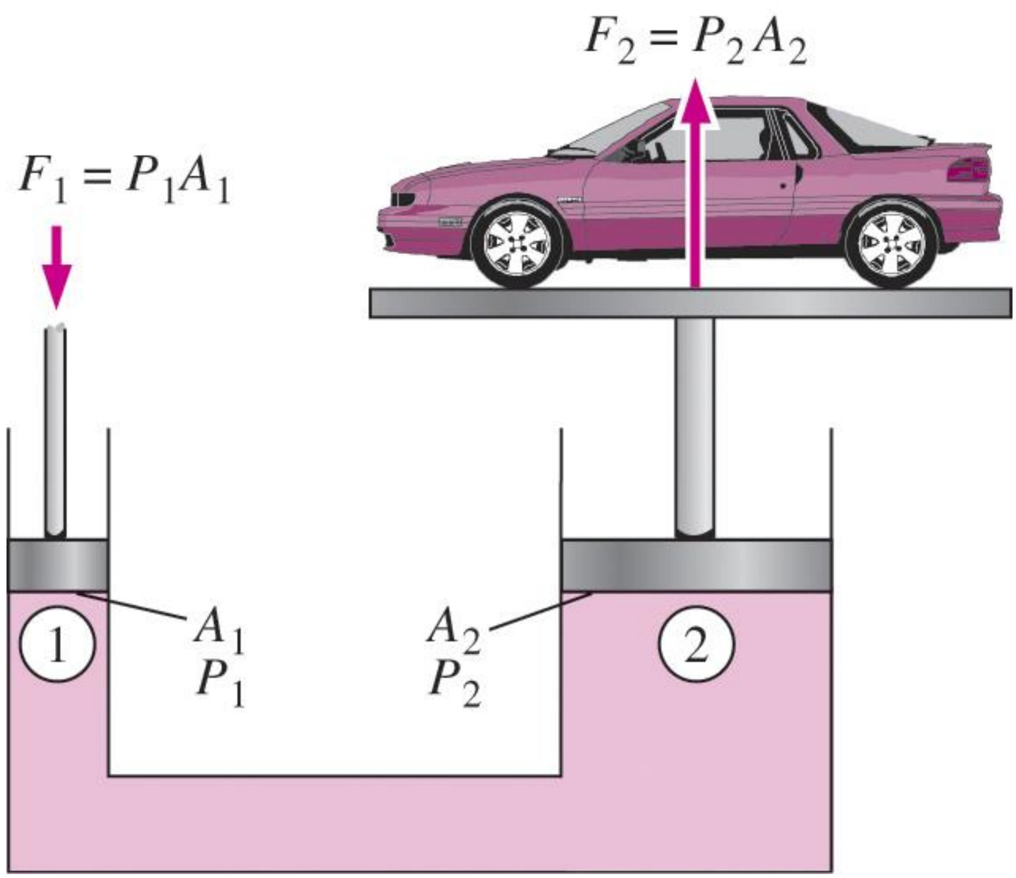


Figure 6: Lifting of a large weight by a small force by the application of Pascal's law.

$$P_1 = P_2 \rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \rightarrow \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

The area ratio A_2/A_1 is called the ideal mechanical advantage of the hydraulic lift.

The Manometer: It is commonly used to measure small and moderate pressure differences. A manometer contains one or more fluids such as mercury, water, alcohol, or oil.

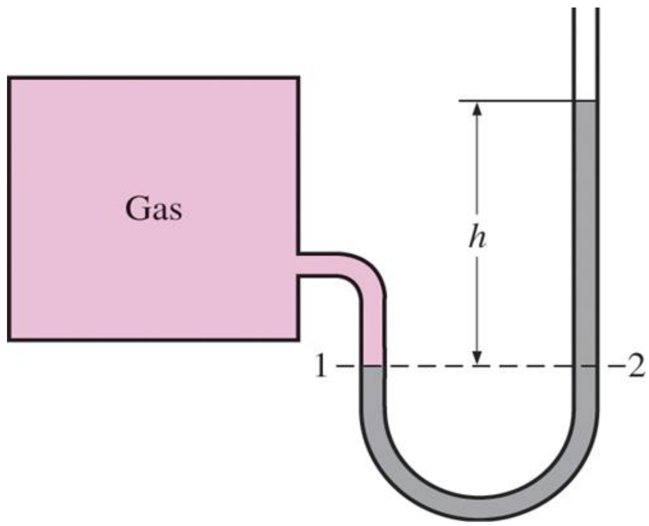
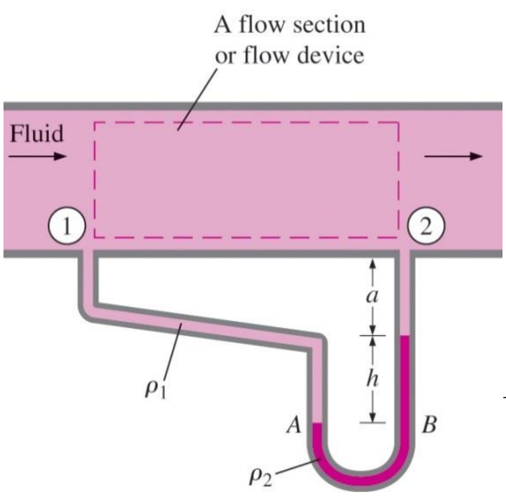


Figure 7: The basic manometer.

Consider the manometer shown in Fig.1.6, that is used to measure the pressure in the tank. Since the gravitational effects of gases are negligible, the pressure anywhere in the tank and at position 1 has the same value. Furthermore, since pressure in a fluid does not vary in the horizontal direction within a fluid, the pressure at point 2 is the same as the pressure at point 1, $P2 = P1$. The differential fluid column of height h is in static equilibrium, and it is open to the atmosphere. Then the pressure at point 2 is determined directly from Eq. $P = P_{atm} + \rho gh$. In stacked-up fluid layers, the pressure change across a fluid layer of density ρ and height h is ρgh.



$$P_1 + \rho_1 g(a+h) - \rho_2 gh - \rho_1 ga = P_2$$
$$P1 - P2 = (\rho_2 - \rho_1) gh$$

$$P_{atm} + \rho_1 gh_1 + \rho_2 gh_2 + \rho_3 gh_3 = P_1$$

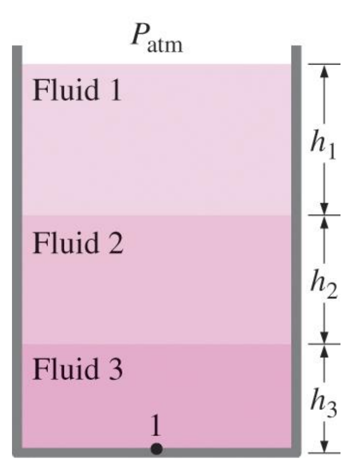


Figure 8: Measuring the pressure drop across a flow section or a flow device by a differential manometer.

Other Pressure Measurement Devices

Bourdon tube: Consists of a hollow metal tube bent like a hook whose end is closed and connected to a dial indicator needle.

Pressure transducers: Use various techniques to convert the pressure effect to an electrical effect such as a change in voltage, resistance, or capacitance.

Pressure transducers are smaller and faster, and they can be more sensitive, reliable, and precise than their mechanical counterparts.

Strain-gage pressure transducers: Work by having a diaphragm deflect between two chambers open to the pressure inputs.

Piezoelectric transducers: Also called solid-state pressure transducers, work on the principle that an electric potential is generated in a crystalline substance when it is subjected to mechanical pressure.

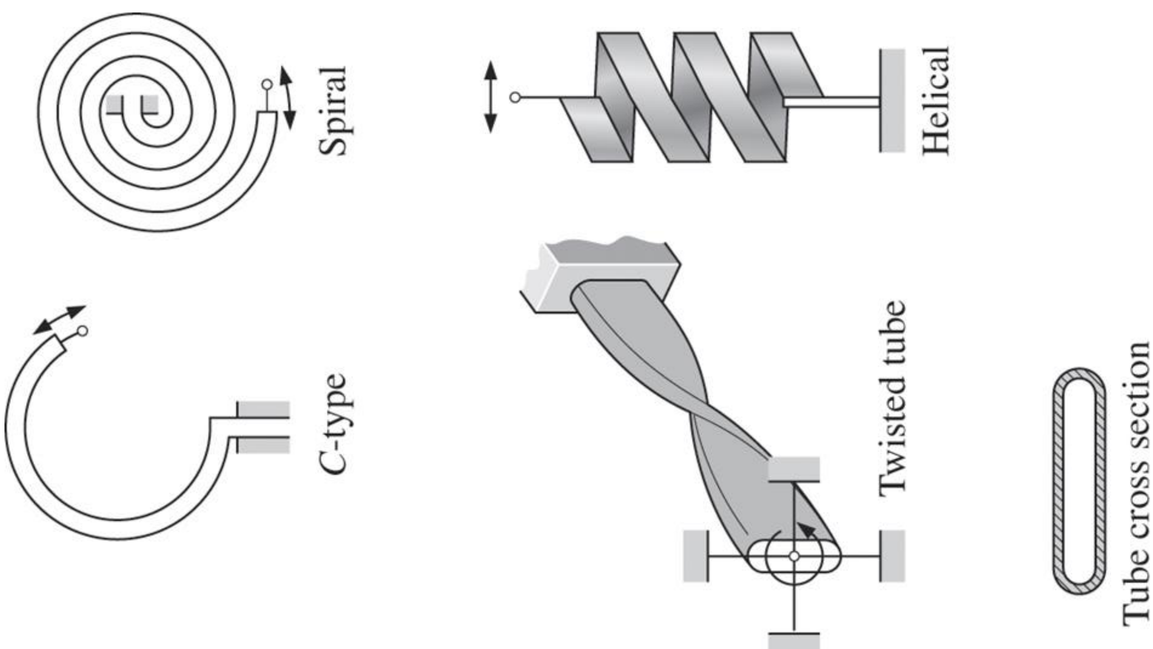


Figure 9: Various types of Bourdon tubes used to measure pressure.

THE BAROMETER AND ATMOSPHERIC PRESSURE: Atmospheric pressure is measured by a device called a barometer; thus, the atmospheric pressure is often referred to as the *barometric pressure*. A frequently used pressure unit is the *standard atmosphere*, which is defined as the pressure produced by a column of mercury 760 mm in height at 0°C (ρ_{Hg} = 13,595 kg/m^3) under standard gravitational acceleration (g = 9.807 m/s^2). The length or the cross-sectional area of the tube has no effect on the height of the fluid column of a barometer, provided that the tube diameter is large enough to avoid surface tension (capillary) effects.

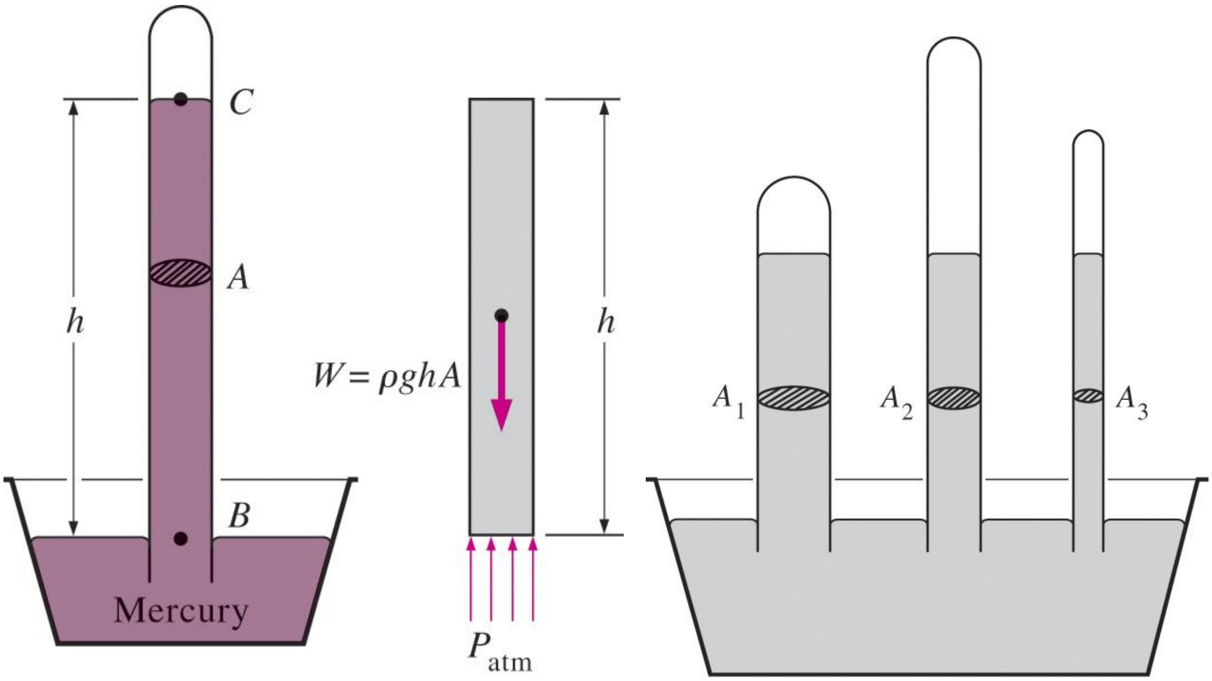


Figure 10: Basic barometer

Property: Any characteristic of a system. Some familiar properties are pressure P, temperature T, volume V, and mass m. Properties are considered to be either intensive or extensive.
Intensive properties: Those that are independent of the mass of a system, such as temperature, pressure and density.
Extensive properties: Those whose values depend on the size—or extent—of the system.
Specific properties: Extensive properties per unit mass.

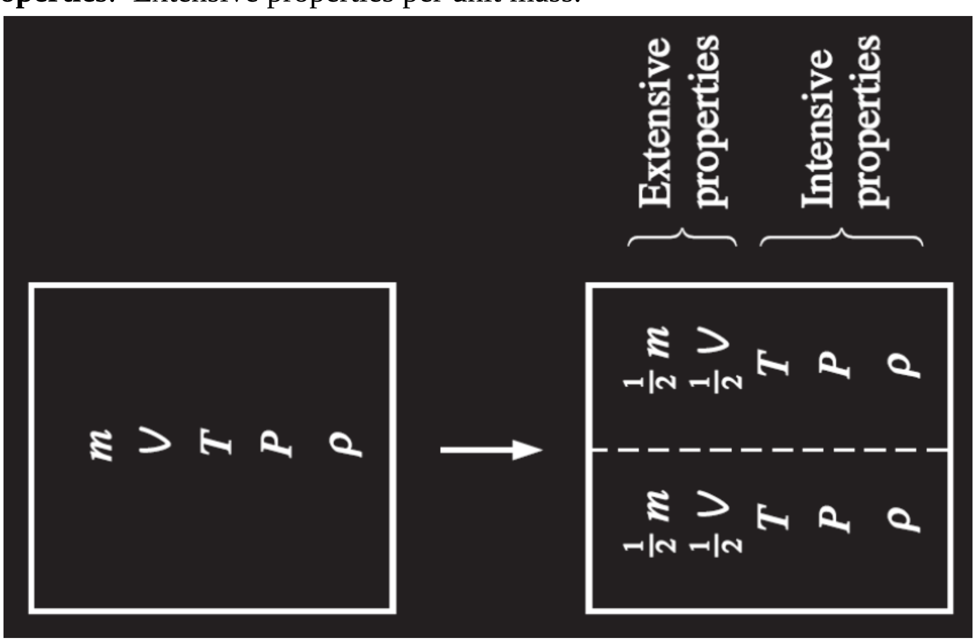


Figure 11: Criterion to differentiate intensive and extensive properties.

The ratio of the extensive property to the mass is called the specific value of that property. Specific volume, $v = V/m = 1/\rho$ (ρ is the density) ,specific internal energy, $u = U/m$. Similarly, the molar properties are defined as the ratios of the properties to the mole number (N) of the substance Molar volume =$v = V/N$, Molar internal energy = $u= U/N$

1.3 PROCEDURE:

The compressor is turned on so that highly pressurized air can enter into the Nozzle Distribution Unit. Set the pressure on the distribution unit to the desired bars and noted down the readings. Repeat the experiment for different values of pressures.

1.4 CALCULATIONS:

N/A

Table 1: Observations and calculations of operating parameters of Nozzle Distribution unit

No. of Obs.	Pressure before distribution (Bars)	P1 (Bars)	P2 (Bars)	P3 (Bars)	P4 (Bars)	P5 (Bars)	P6 (Bars)	Pressure after distribution (Bars)
1.								
2.								
3.								
4.								
5.								
6.								

1.5 SPECIMEN CALCULATION: (for first set of readings)

N/A

PLOTS: Draw the following plots:

1- Plot graph between the pressure before distribution and after distribution

1.6 COMMENTS:

LAB SESSION NO: 02

THERMODYNAMICS FOR TECHNOLOGIST

DEAD WEIGH CALIBRATOR

OBJECTIVE

To Calibrate Bourdon Manometer for the determination of hysteresis.

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Figure 12: Nozzle Distribution Unit

2. OBJECTIVE

To Calibrate Bourdon Manometer for the determination of hysteresis.

2.1 APPARATUS:

Dead weight calibrator and set of masses.

2.2 SCHEMATIC DIAGRAM:

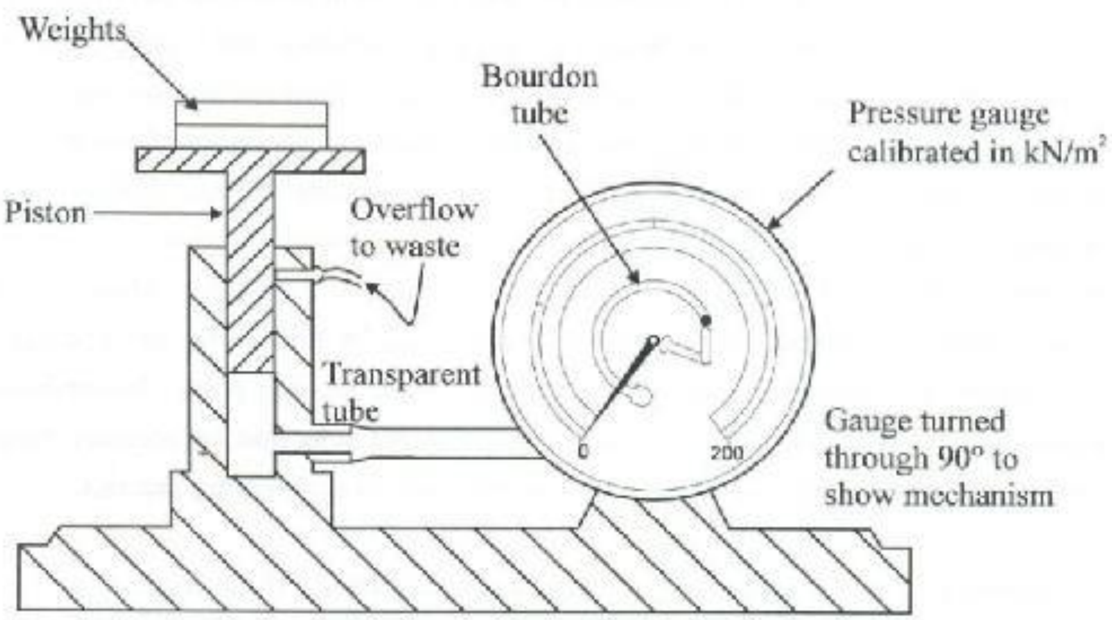

Fig 3.1 Apparatus for calibration of pressure gauge

Figure 13: Schematic diagram of nozzle distribution unit

2.3 APPARATUS DESCRIPTION:

1. This unit enables a wide range of investigations and studies into pressure measurement techniques, using Bourdon type pressure gauges to understand the operation the characteristic of the devices, and to study the principles of calibration and to do practical exercises and experiments about it.
2. Pressure Measurement and Calibration Unit is designed to study pressure and how different methods and techniques can be used to measure this variable.
3. This unit introduces students to pressure, pressure scales and common devices available to measure pressure.

4. It comprises a dead-weight pressure calibrator to generate a number of predetermined pressures, connected to a Bourdon type manometer to allow their characteristics, including accuracy and linearity, to be determined.
5. Using the dead-weight pressure calibrator different fixed pressures are generated for calibrating the measuring elements. The dead-weight pressure calibrator consists of a precision piston and cylinder with a set of weights.
6. The Bourdon type manometer is mounted on a manifold block with a separate reservoir to contain the water.
7. Valves allow for easy priming, restricted flow of water to demonstrate the application of damping and the connection of alternative devices for calibration.

2.4 APPARATUS SPECIFICATIONS:

Bourdon gauge with dead-weight calibrator module:

- Anodized aluminum structure and panel in painted steel (epoxy paint), and main metallic elements in stainless steel.
- Diagram in the panel with similar distribution to the elements in the real unit.
- Dead-weight calibrator consists of a piston, with is free to move vertically, in cylinder. Flexible hose connects the cylinder with the Bourdon pressure gauge. A set of weights are included.
- Bourdon type gauge with internal mechanism clearly visible through the transparent dial.
- The module can be leveled with the help of adjustable feet.

2.5 THEORY:

2.5.1 Calibration:

It is defined as the process of comparison of specific values of input and output of instrument with the corresponding reference standards. Calibration must be performed periodically to test the validity of performance of device or system.

2.5.2 BOURDON TUBE

- Bourdon Tubes are known for its very high range of differential pressure measurement in the range of almost 100,000 psi (700 MPa). It is an elastic type pressure transducer.
- The device was invented by Eugene Bourdon in the year 1849. The basic idea behind the device is that, cross-sectional tubing when deformed in any way will tend to regain its circular form under the action of pressure.
- The bourdon pressure gauges used today have a slight elliptical cross-section and the tube is generally bent into a C-shape or arc length of about 27 degrees. The detailed diagram of the bourdon tube is shown Figure 14.

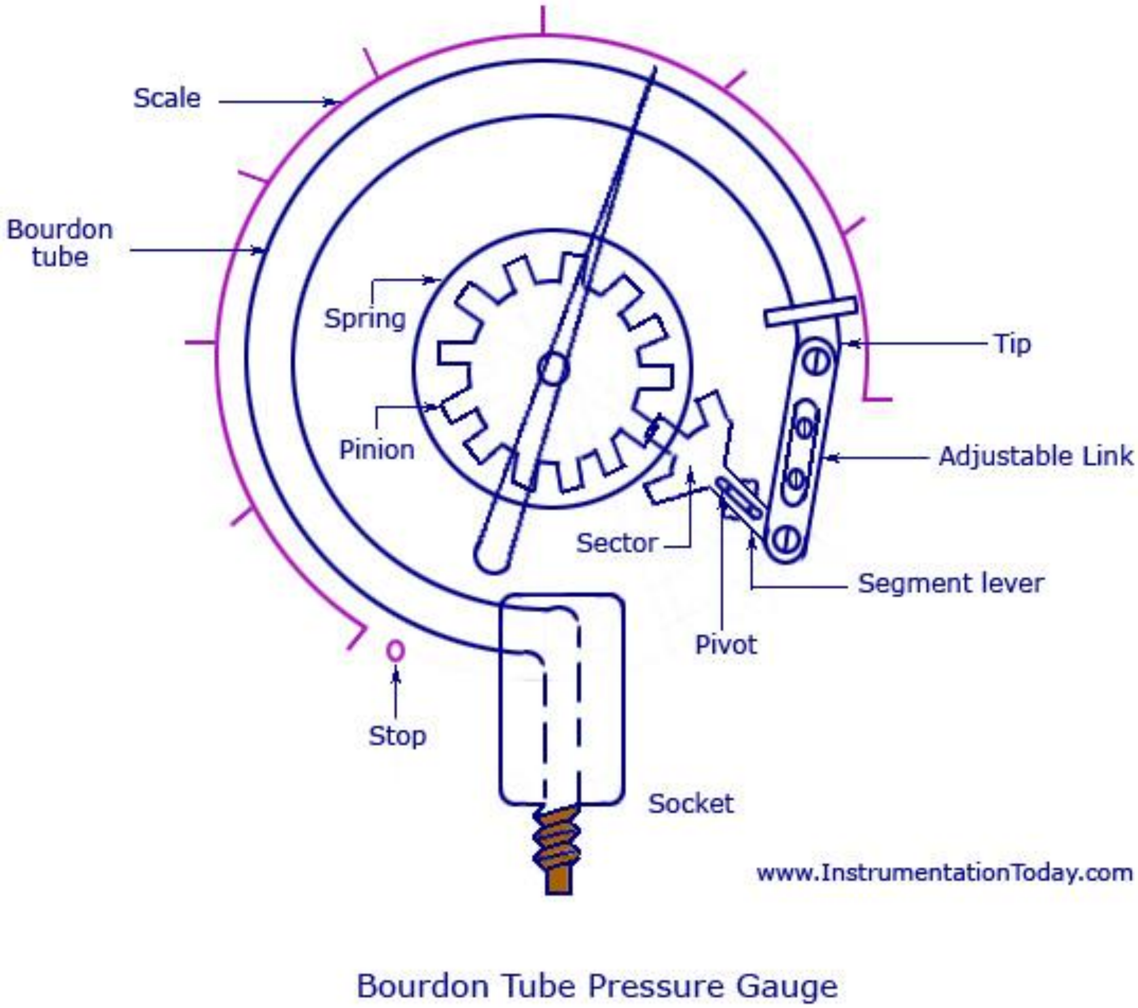

Figure 14: Bourdon monomeric pressure gauge

- As seen in the figure, the pressure input is given to a socket which is soldered to the tube at the base. The other end or free end of the device is sealed by a tip. This tip is connected to a segmental lever through an adjustable length link. The lever length may also be adjustable. The segmental lever is suitably pivoted and the spindle holds the pointer as shown in the figure. A hair spring is sometimes used to fasten the spindle of the frame of the instrument to provide necessary tension for proper meshing of the gear teeth and thereby freeing the system from the backlash.

- Any error due to friction in the spindle bearings is known as lost motion. The mechanical construction has to be highly accurate in the case of a Bourdon Tube Gauge. If we consider a cross-section of the tube, its outer edge will have a larger surface than the inner portion. The tube walls will have a thickness between 0.01 and 0.05 inches.

Working:

- As the fluid pressure enters the bourdon tube, it tries to be reformed and because of a free tip available, this action causes the tip to travel in free space and the tube unwinds. The simultaneous actions of bending and tension due to the internal pressure make a non-linear movement of the free tip.

- This travel is suitable guided and amplified for the measurement of the internal pressure. But the main requirement of the device is that whenever the same pressure is applied, the movement of the tip should be the same and on withdrawal of the pressure the tip should return to the initial point.

- A lot of compound stresses originate in the tube as soon as the pressure is applied. This makes the travel of the tip to be non-linear in nature. If the tip travel is considerably small, the stresses can be considered to produce a linear motion that is parallel to the axis of the link. The small linear tip movement is matched with a rotational pointer movement. This is known as multiplication, which can be adjusted by adjusting the length of the lever.

- For the same amount of tip travel, a shorter lever gives larger rotation. The approximately linear motion of the tip when converted to a circular motion with the link-lever and pinion attachment, a one-to-one correspondence between them may not occur and distortion results. This is known as angularity which can be minimized by adjusting the length of the link.

- Other than C-type, bourdon gauges can also be constructed in the form of a helix or a spiral. The types are varied for specific uses and space accommodations, for better linearity and larger sensitivity. For thorough repeatability, the bourdon tubes materials must have good elastic or spring characteristics.

- The surrounding in which the process is carried out is also important as corrosive atmosphere or fluid would require a material which is corrosion proof. The commonly used materials are phosphor-bronze, silicon-bronze, beryllium-copper, inconel, and other C-Cr-Ni-Mo alloys, and so on.

- In the case of forming processes, empirical relations are known to choose the tube size, shape and thickness and the radius of the C-tube. Because of the internal pressure, the near elliptic or rather the flattened section of the tube tries to expand as shown by the dotted line in the figure below (a). The same expansion lengthwise is shown in figure (b). The arrangement of the tube, however forces an expansion on the outer surface and a compression on the inner surface, thus allowing the tube to unwind. This is shown in figure (c).

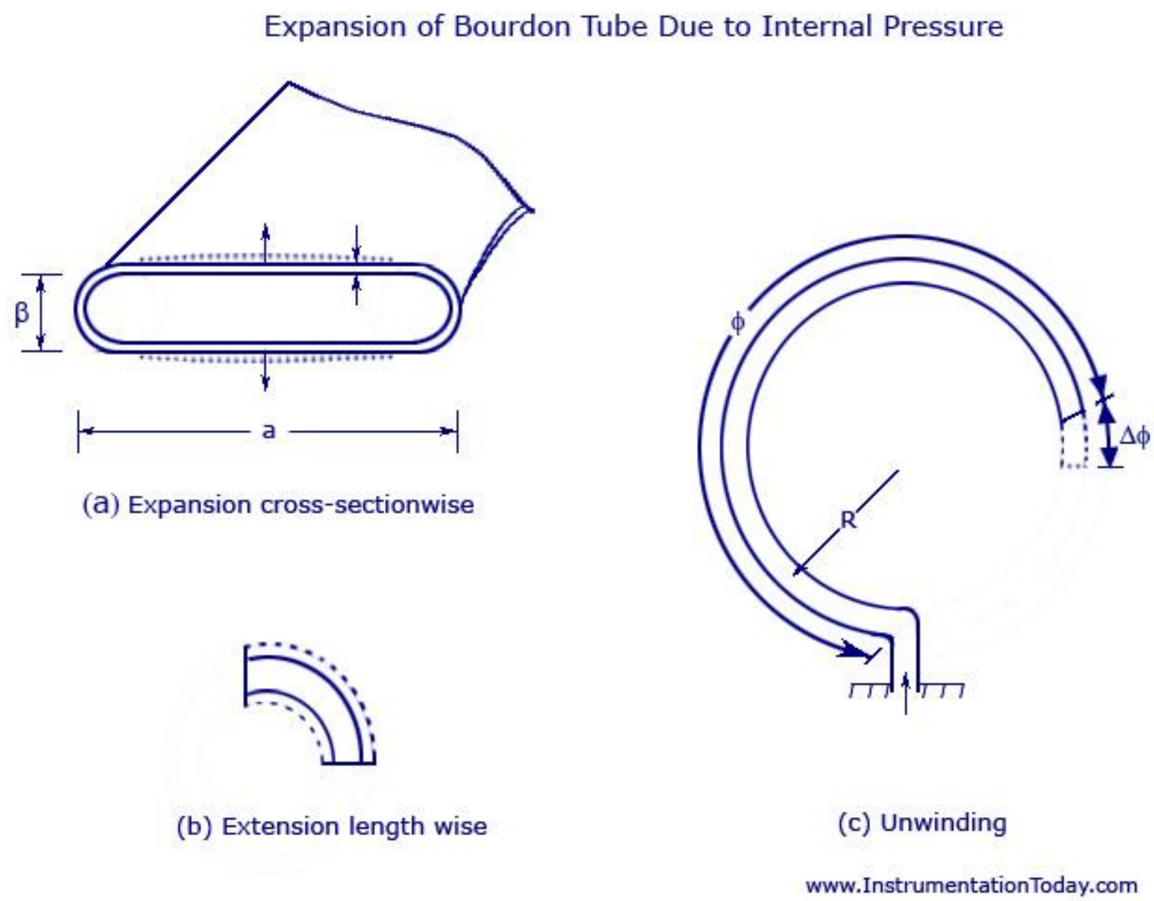

Figure 15: Expansion of Bourdon Tube Due to Internal Pressure

- Like all elastic elements a bourdon tube also has some hysteresis in a given pressure cycle. By proper choice of material and its heat treatment, this may be kept to within 0.1 and 0.5 percent of the maximum pressure cycle.
- Sensitivity of the tip movement of a bourdon element without restraint can be as high as 0.01 percent of full range pressure reducing to 0.1 percent with restraint at the central pivot.

2.6 DETERMINATION OF HYSTERISIS CURVE

Hysteresis is the dependence of a system not only on its current environment but also on its past environment. This dependence arises because the system can be in more than one internal state. To predict its future development, either its internal state or its history must be known. If a given input alternately increases and decreases, the output tends to form a loop as in the figure. However, loops may also occur because of a dynamic lag between input and output. Often, this effect is also referred to as hysteresis, or *rate-dependent hysteresis*. This effect disappears as the input changes more slowly; so many experts do not regard it as true hysteresis. Hysteresis occurs in ferromagnetic materials and ferroelectric materials, as well as in the deformation of some materials in response to a varying force. In natural systems hysteresis is often associated with irreversible thermodynamic change. Many artificial systems are designed to have hysteresis:

for example, in thermostats hysteresis is produced by positive feedback to avoid unwanted rapid switching. Hysteresis has been identified in many other fields, including economics and biology.

2.7 PROCEDURE:

Measure the masses of dead weights by using a precision balance. Placed the equipment on a flat surface and connect the supply tubes that connect the inferior area of cylinder to the input of the manometer. Disassemble the piston and determined accurately its weight. Open the faucet of the manometer and eliminate the air from the system. Apply petroleum jelly on the piston, fill the cylinder with water and place the piston in the cylinder. Record the reading of the manometer and the mass of the cylinder. Repeat the experiment by gradually increasing the mass of the system and then by decreasing the masses.

2.8 CALCULATIONS:

Diameter of Piston = d= 18 mm = 0.018 m.

Area of Piston = A =$\pi d^2/4$ = $3.142(0.018)^2/4$ = 0.000255 m^2

We will find the Pressure in the Cylinder by using the formula P = F/A

We convert bars into KN/m^2 by;

1 bar = 10^5 N/m^2 = $10^2 KN/m^2$

Table 2: Observations and calculations of operating parameters of Nozzle Distribution unit (Ascending Order)

Mass of Piston (Kg)	Pressure in cylinder	Manometer Readings	Manometer Readings	Absolute error (KN/m^2)	Relative Error %
M	X (kN/m^2)	X_O(Bars)	X_O (kN/m^2)	" $X-X_0$ "	$\|X-X_0\|/X\times100$
0.0					
0.5					
1.0					
1.5					
2.0					
3.0					

Table 3: Observations and calculations of operating parameters of Nozzle Distribution unit (Descending Order)

Mass of Piston (Kg)	Pressure in cylinder	Manometer Readings	Manometer Readings	Absolute error (KN/m^2)	Relative Error %
M	X (kN/m^2)	X_O(Bars)	X_O (kN/m^2)	" $X-X_0$ "	$\|X-X_0\|/X\times100$
0.0					
0.5					
1.0					
1.5					
2.0					
3.0					

Table 4: Observations and calculations of operating parameters of Nozzle Distribution unit (Average)

Mass of Piston (Kg)	Pressure in cylinder	Manometer Readings	Manometer Readings	Absolute error (KN/m^2)	Relative Error %
M	X (kN/m^2)	X_O(Bars)	X_O (kN/m^2)	" $X-X_0$ "	$\|X-X_0\|/X\times100$
0.0					
0.5					
1.0					
1.5					
2.0					
3.0					

2.9 SPECIMEN CALCULATION: (for first set of readings)

PLOTS: Draw the following plots:

GRAPH:

Graph between absolute error in a function of the real pressure in the manometer.

Graph between relative error in a function of the real pressure in the manometer.

Draw a graph between real pressure in KN/m^2 and manometer pressure in KN/m^2 for ascending and descending readings.

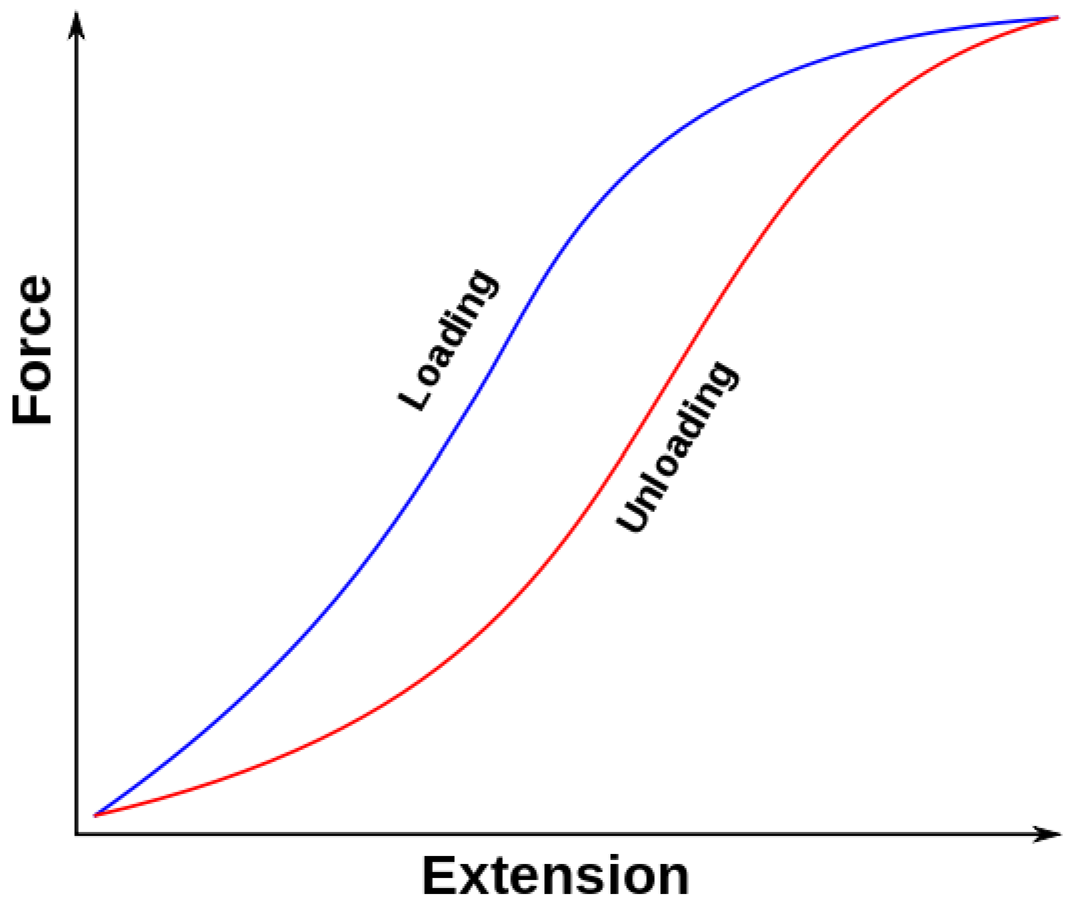

Figure 16: Hysteresis Loop formation

2.10 COMMENTS:

LAB SESSION NO: 03

THERMODYNAMICS FOR TECHNOLOGIST

INTERNAL COMBUSTION ENGINE

OBJECTIVE

Study of general characteristics terms and components of internal combustion engines.

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Figure 17: Internal Combustion Engine

3. OBJECTIVE

Study of general characteristics terms and components of internal combustion engines

3.1 APPARATUS:

Internal Combustion Engine

3.2 SCHEMATIC DIAGRAM:

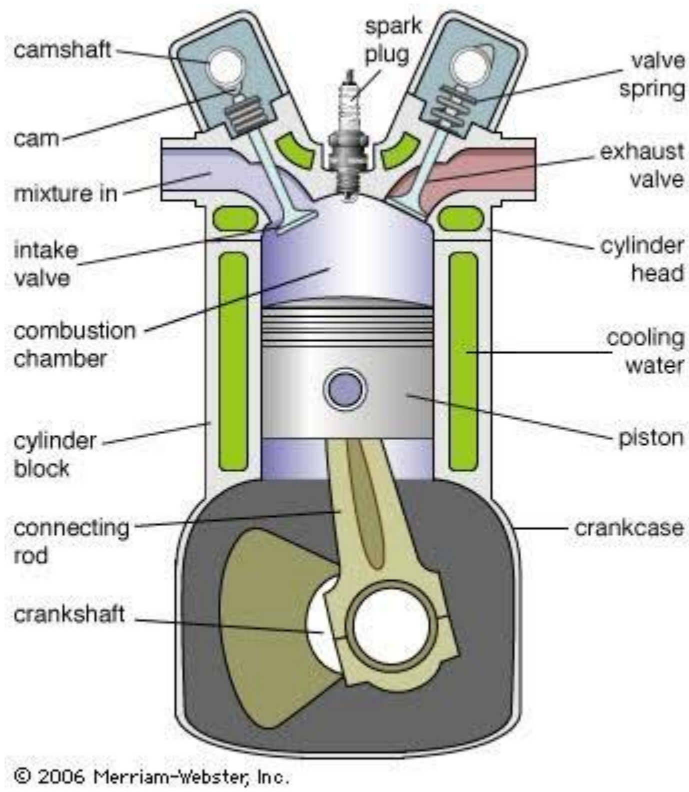

Figure 18: Schematic diagram of 4-stroke engine

3.3 THEORY:

3.3.1 Engine:

"A machine for converting energy into mechanical force and motion."

3.3.2 Heat Engine

Heat engine is a machine for converting heat, developed by burning fuel into useful work. It can be said that heat engine is equipment which generates thermal energy and transforms it into mechanical energy.

3.3.3 CLASSIFICATION OF HEAT ENGINES

1. Based on combustion of fuel:

(i) External combustion engine (ii) Internal combustion engine.

External combustion engine: Here, the working medium, the steam, is generated in a boiler, located outside the engine and allowed in to the cylinder to operate the piston to do mechanical work.

Internal combustion engine: In internal combustion engine, the combustion of fuel takes place inside the engine cylinder and heat is generated within the cylinder. This heat is added to the air inside the cylinder and thus the pressure of the air is increased tremendously. This high pressure air moves the piston which rotates the crank shaft and thus mechanical work is done

2. Based on fuel used

1. Diesel engine 2. Petrol engine 3. Gas engine
Diesel engine – Diesel is used as fuel
Petrol engine – Petrol is used as fuel
Gas engines – propane, butane or methane gases are used
3. Based ignition of fuel
1. Spark ignition engine (Carburetor type engines)
2. Compression ignition engine (injector type engines)

Spark ignition engine – a mixture of air and fuel is drawn in to the engine cylinder. Ignition of fuel is done by using a spark plug. The spark plug produces a spark and ignites the air- fuel mixture. Such combustion is called constant volume combustion (C.V.C.).

Compression ignition engine – In compression ignition engines air is compressed in to the engine cylinder,. Due to this the temperature of the compressed air rises to 700-900 C. At this stage diesel is sprayed in to the cylinder in fine particles. Due to a very high temperature, the fuel gets ignited. This type of combustion is called constant pressure combustion (CP.C.) because the pressure inside the cylinder is almost constant when combustion is taking place.

4. Based on working cycle

1. Four stroke cycle engine - When the cycle is completed in two revolutions of the crankshaft, it is called four stroke cycle engines.

2. Two stroke cycle engine. - When the cycle is completed in one revolution of the crankshaft, it is called two stroke cycle engines.

3.3.4 CONSTRUCTION OF AN IC ENGINE

I.C. engine converts the reciprocating motion of piston into rotary motion of the crankshaft by means of a connecting rod. The piston which reciprocating in the cylinder is very close fit in the cylinder. Rings are inserted in the circumferential grooves of the piston to prevent leakage of gases from sides of the piston. Usually a cylinder is bored in a cylinder block and a gasket, made of copper sheet or asbestos is inserted between the cylinder and the cylinder head to avoid ant leakage. The combustion space is provided at the top of the cylinder head where combustion takes place. The connecting rod connects the piston and the crankshaft. The end of the connecting rod connecting the piston is called small end. A pin called gudgeon pin or wrist pin is provided for connecting the piston and the connecting rod at the small end. . The other end of the connecting rod connecting the crank shaft is called big end. When piston is moved up and down, the motion is transmitted to the crank shaft by the connecting rod and the crank shaft makes rotary motion. The crankshaft rotates in main bearings which are fitted the crankcase. A flywheel is provided at one end of the crankshaft for smoothing the uneven torque produced by the engine. There is an oil sump at the bottom of the engine which contains lubricating oil for lubricating different parts of the engine.

3.3.4.1 Cylinder Block

Function- In the bore of cylinder the fresh charge of air-fuel mixture is ignited, compressed by piston and expanded to give power to piston.

Figure 19: Cylinder block of an internal combustion engine

3.3.4.2 Cylinder Head

Function-It carries inlet and exhaust valve. Fresh charge is admitted through inlet valve and burnt gases are exhausted from exhaust valve. In case of petrol engine,a spark plug and in case of diesel engine, a injector is also mounted on cylinder head.

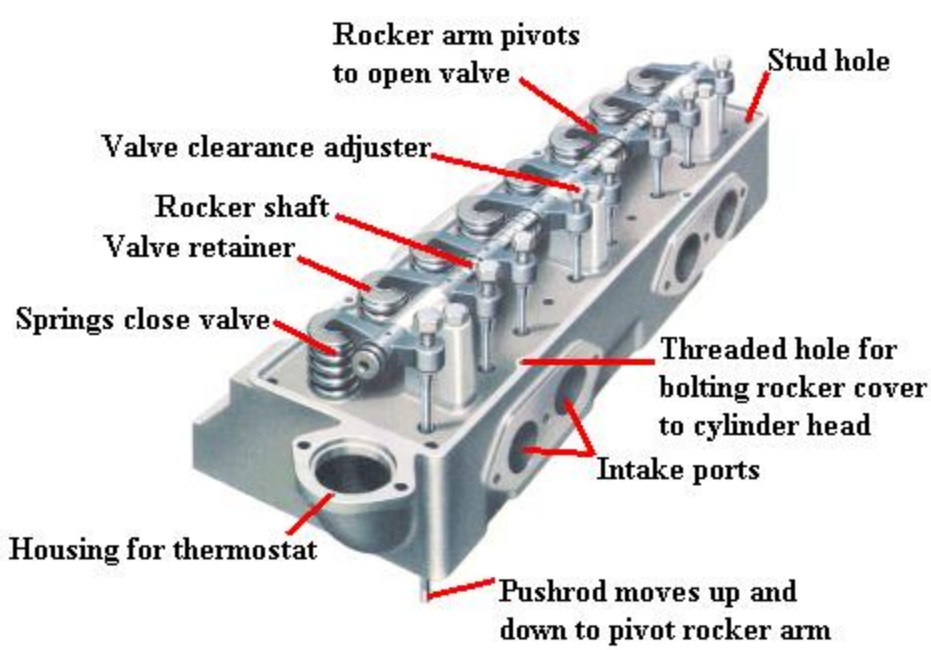

Figure 20: Cylinder head of an internal combustion engine

3.3.4.3 Piston:

Function-During suction stroke,it sucks the fresh charge of air-fuel mixture through inlet valve and compresses during the compression stroke inside the cylinder.This way piston receives power from the expanding gases after ignition in cylinder.Also forces the burnt exhaust gases out of the cylinder through exhaust valve.

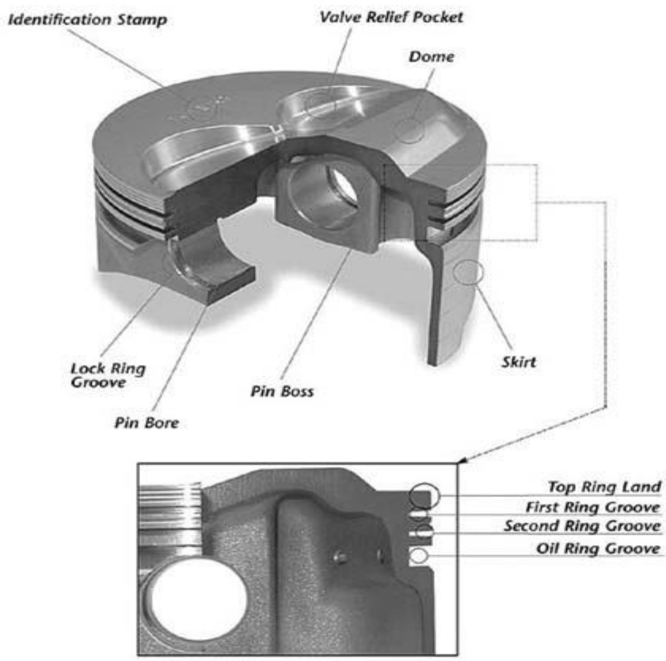

Figure 21: Piston of an internal combustion engine

3.3.4.4 Piston Rings

Function-It prevents the compressed charge of fuel-air mixture from leaking to the other side of the piston. Oil rings, is used for removing lubricating oil from the cylinder after lubrication. This ring prevents the excess oil to mix with charge.

Figure 22: Piston rings of an internal combustion engine

3.3.4.5 Connecting Rod

Function-It changes the reciprocating motion of piston into rotary motion at crank shaft. This way connecting rod transmits the power produced at piston to crankshaft.

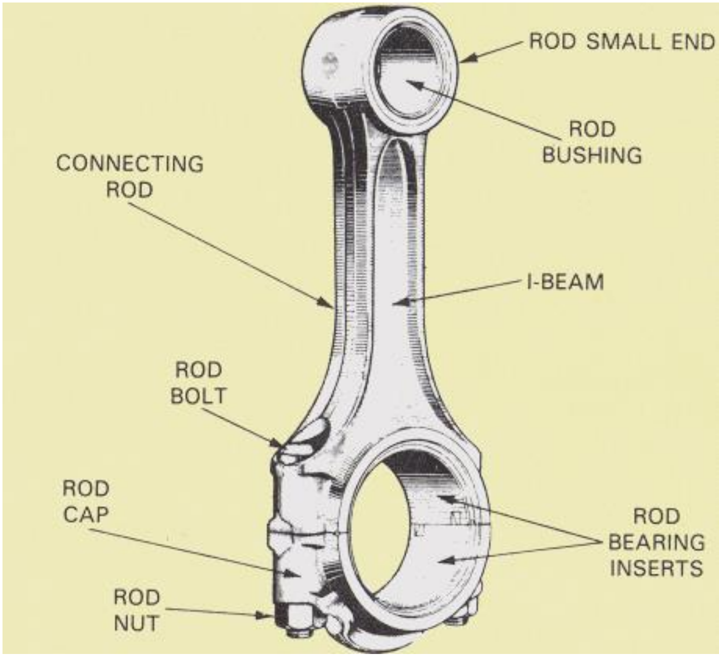

Figure 23: Piston rings of an internal combustion engine

3.3.4.6 Gudgeon Pin

Function-Connects the piston with small end of connecting rod.

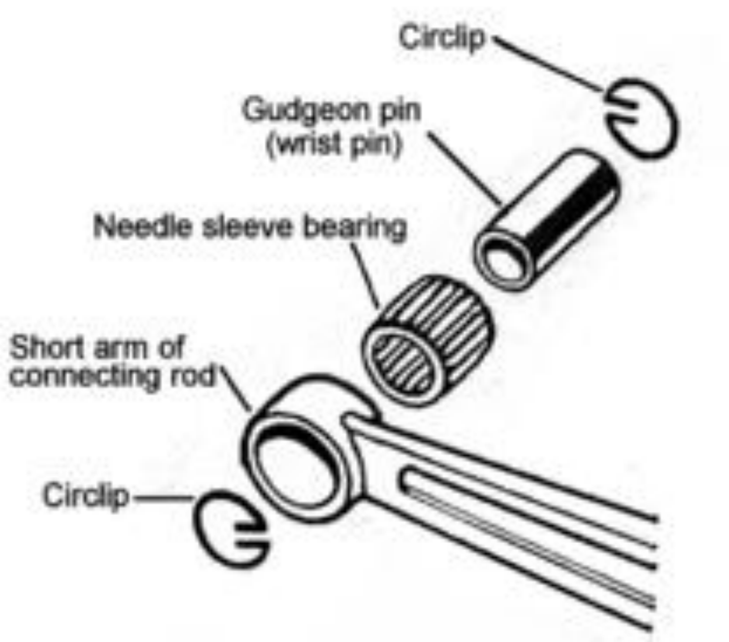

Figure 24: Gudgeon pin of an internal combustion engine

3.3.4.7 Crank Pin

Function-hand over the power and motion to the crank shaft which come from piston through connecting rod.

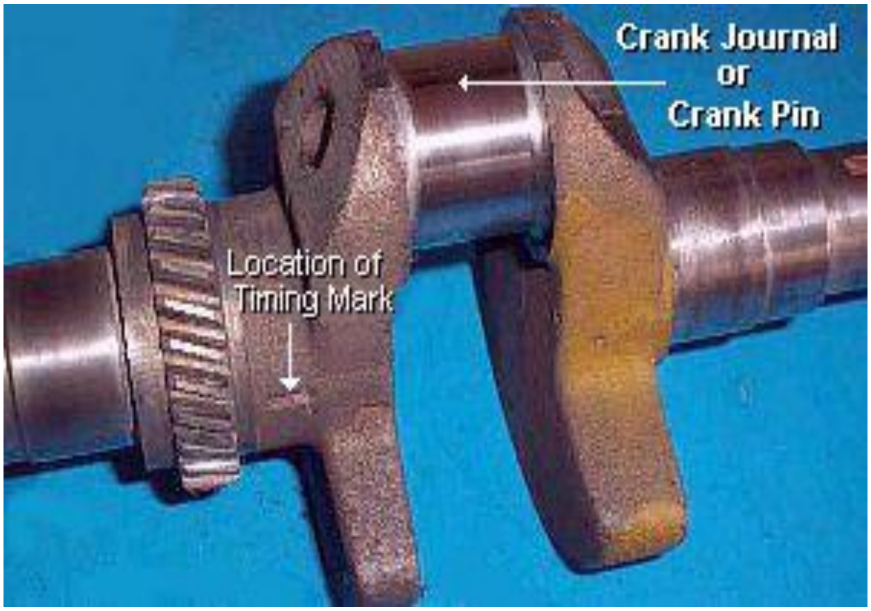

Figure 25: Crank pin of an internal combustion engine

3.3.4.8 Crank Shaft

Function-Receives oscillating motion from connecting rod and gives a rotary motion to the main shaft. It also drives the camshaft which actuates the valves of the engine. It takes driving force from crankshaft through gear train or chain and operates the inlet valve as well as exhaust valve with the help of cam followers, push rod and rocker arms.

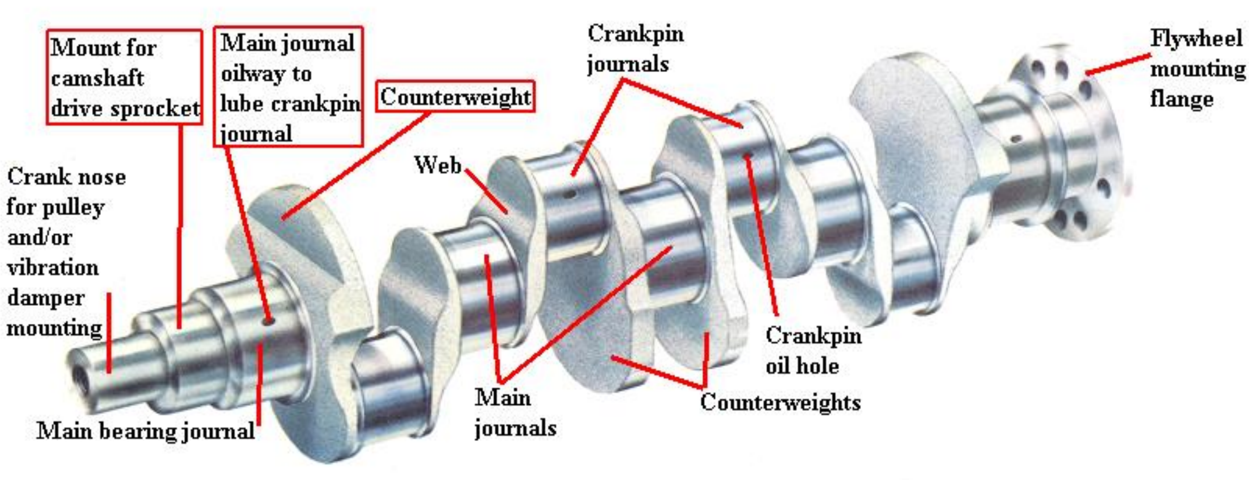

Figure 26: Crank pin of an internal combustion engine

3.3.4.9 Inlet Valve & Exhaust Valve

Function-Inlet valve allow the fresh charge of air-fuel mixture to enter the cylinder bore. Exhaust valve permits the burnt gases to escape from the cylinder bore at proper timing.

Figure 27: Intake and exhaust valves of an internal combustion engine

3.3.4.10 Governor

Function-It controls the speed of engine at a different load by regulating fuel supply in diesel engine. In petrol engine, supplying the mixture of air-petrol and controlling the speed at various load condition.

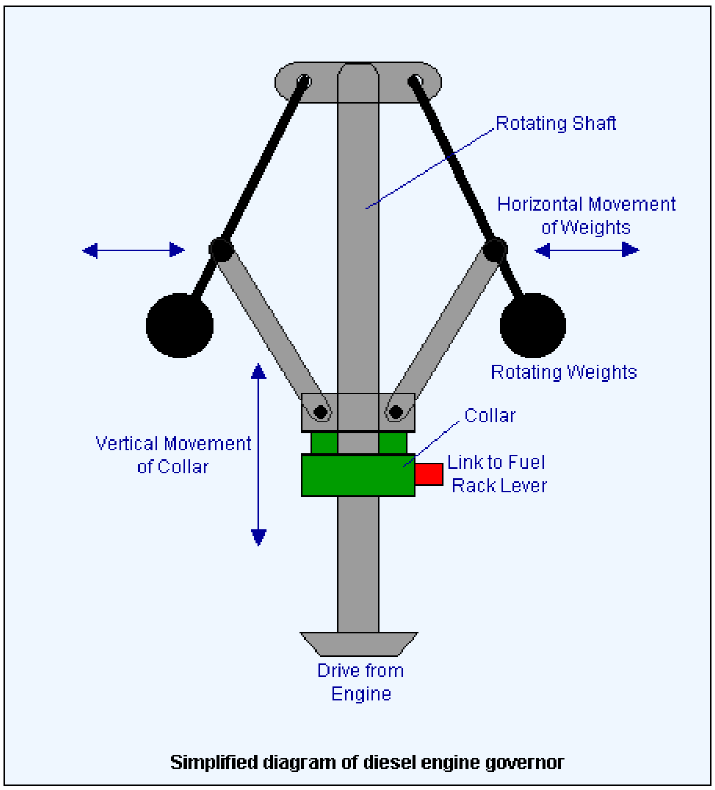

Figure 28: Governor used in an internal combustion engine

3.3.4.11 Carburettor

Function-It converts petrol in fine spray and mixes with air in proper ratio as per requirement of the engine.

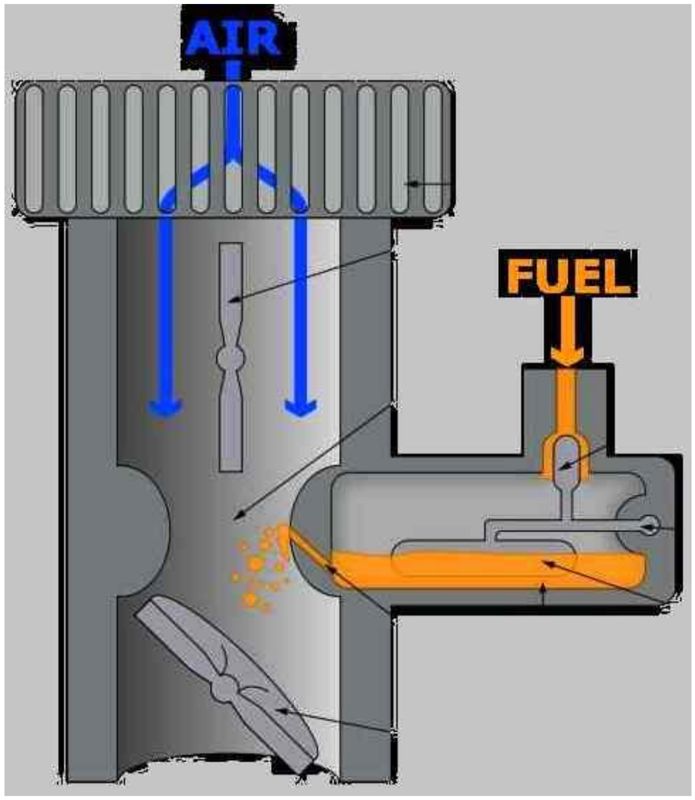

Figure 29: Carburetor used in an internal combustion engine

3.3.4.12 Fuel Pump

Function-This device supply the petrol to the carburetor sucking from the fuel tank.

Figure 30: Fuel injection pump used in an internal combustion engine

3.3.4.13 Spark Plug

Function-This device is used in petrol engine only and ignites the charge of fuel for combustion.

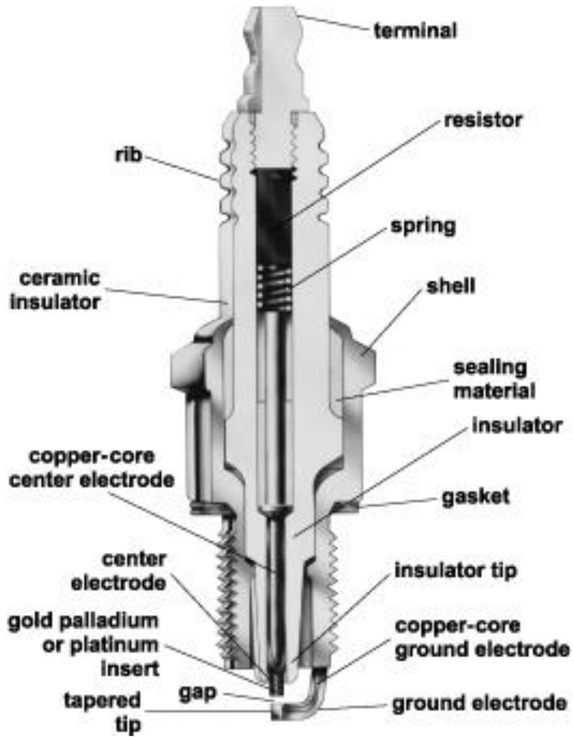

Figure 31: Spark plug used in an internal combustion engine

3.3.4.14 Fuel Injector

Function-This device is used in diesel engine only and delivers fuel in fine spray under pressure.

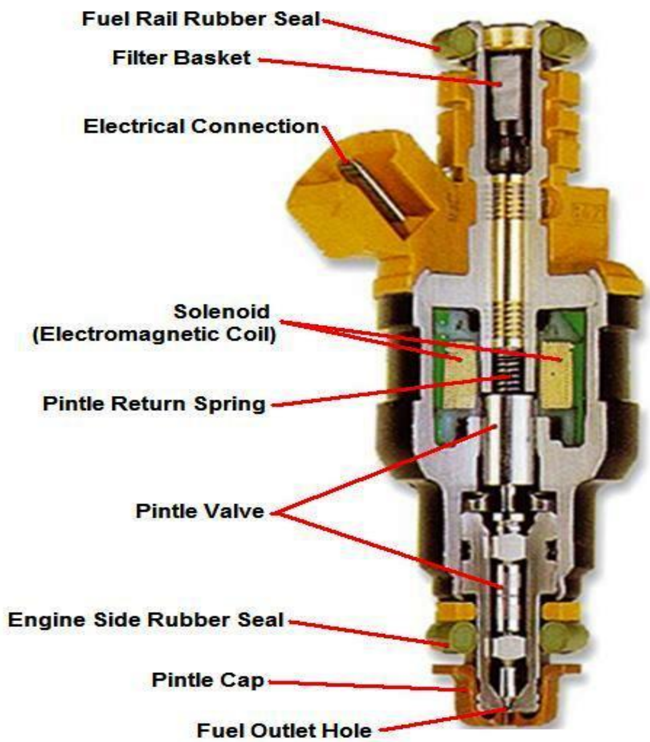

Figure 32: Fuel injector used in an internal combustion engine

3.3.4.15 SOHC Engines Vs. DOHC Engines

Difference:

SOHC stands for Single Overhead Camshaft. That means that there is only one camshaft per header. Inline engines will contain one camshaft. V-type and/or flat will contain 2 camshafts. For a SOHC engine there are usually 2 valves per cylinder but there can be more with the addition of cams for each valve. DOHC stands for Double Overhead Camshaft. Now there are 2 camshafts per header. So in an inline there are 2 camshafts because there is only one header, but there are 4 in a V-type or flat engine. These DOHC engines usually have 4 valves. One camshaft for the exhaust valves and the other for the intake valves. Advantages to having a DOHC engine over a SOHC is that the engine has twice as many intake and exhaust valves as a SOHC motor. This makes the engine run cooler and more smoothly, quietly, and efficiently. But the downfall is that DOHC engines cost more for repairs. To ensure against expensive engine repairs, make sure you change your engine's timing belt about every 60,000 miles.

3.4 COMMENTS:

LAB SESSION NO: 04

APPLIED THERMODYNAMICS-I LABORATORY

SPARK IGNITION ENGINE

OBJECTIVE

Study and experimental demonstration of spark ignition engine (four stroke & two stroke).

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE

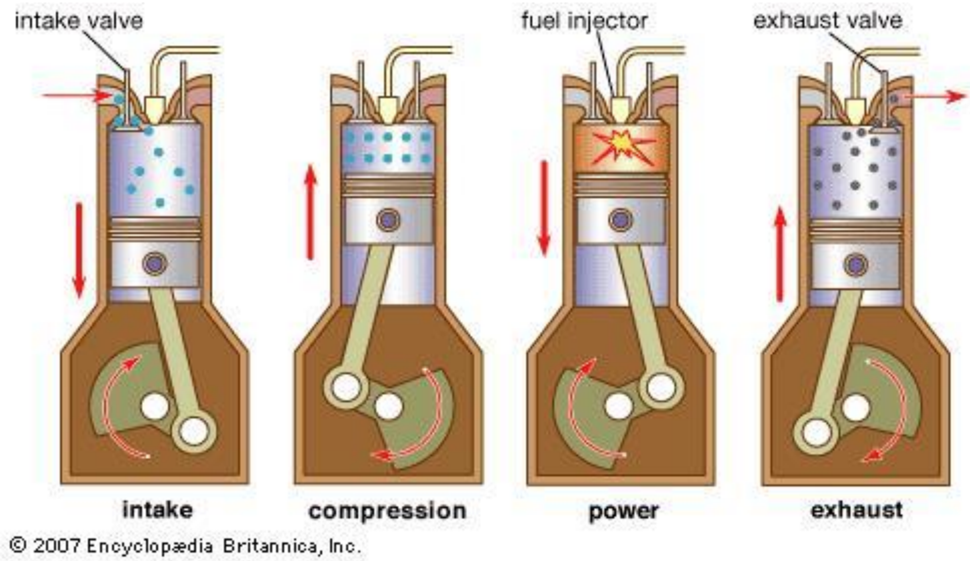

Figure 33: Four stroke petrol engine

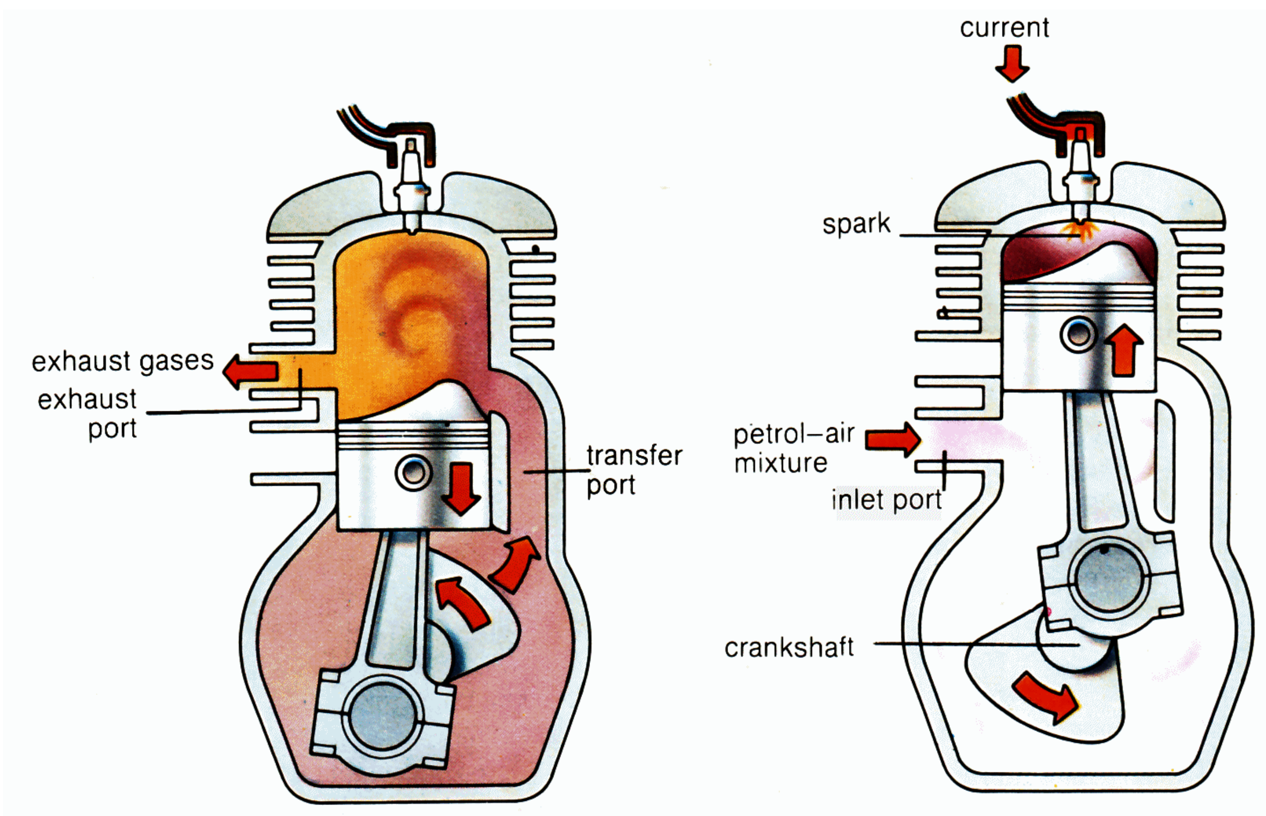

Figure 34: Two stroke petrol engine

4. OBJECTIVE

Study and experimental demonstration of spark ignition engine (four strokes and two strokes).

4.1 APPARATUS:

Cut models of four stroke and two stroke petrol engines.

4.2 SCHEMATIC DIAGRAM:

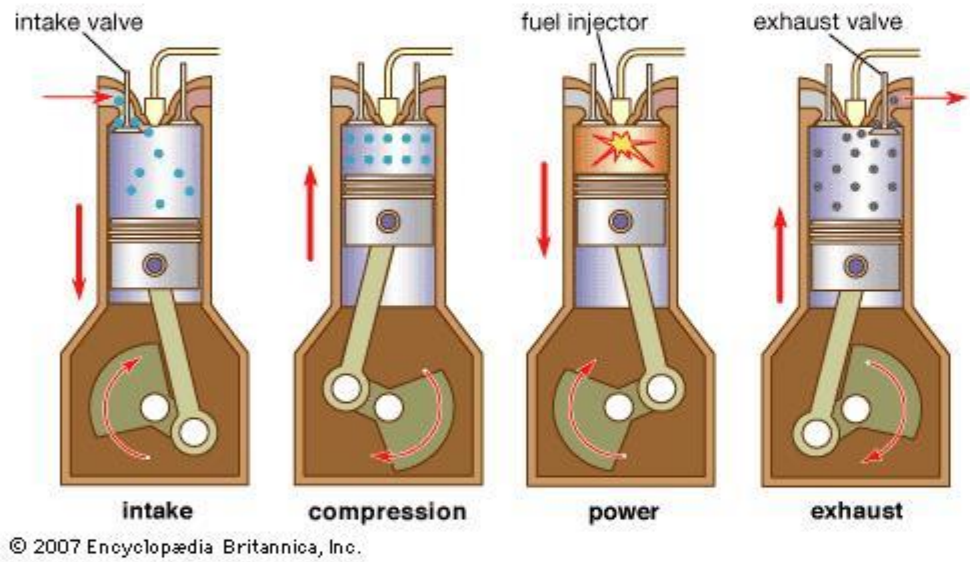

Figure 35: Schematic diagram of four stroke petrol engine

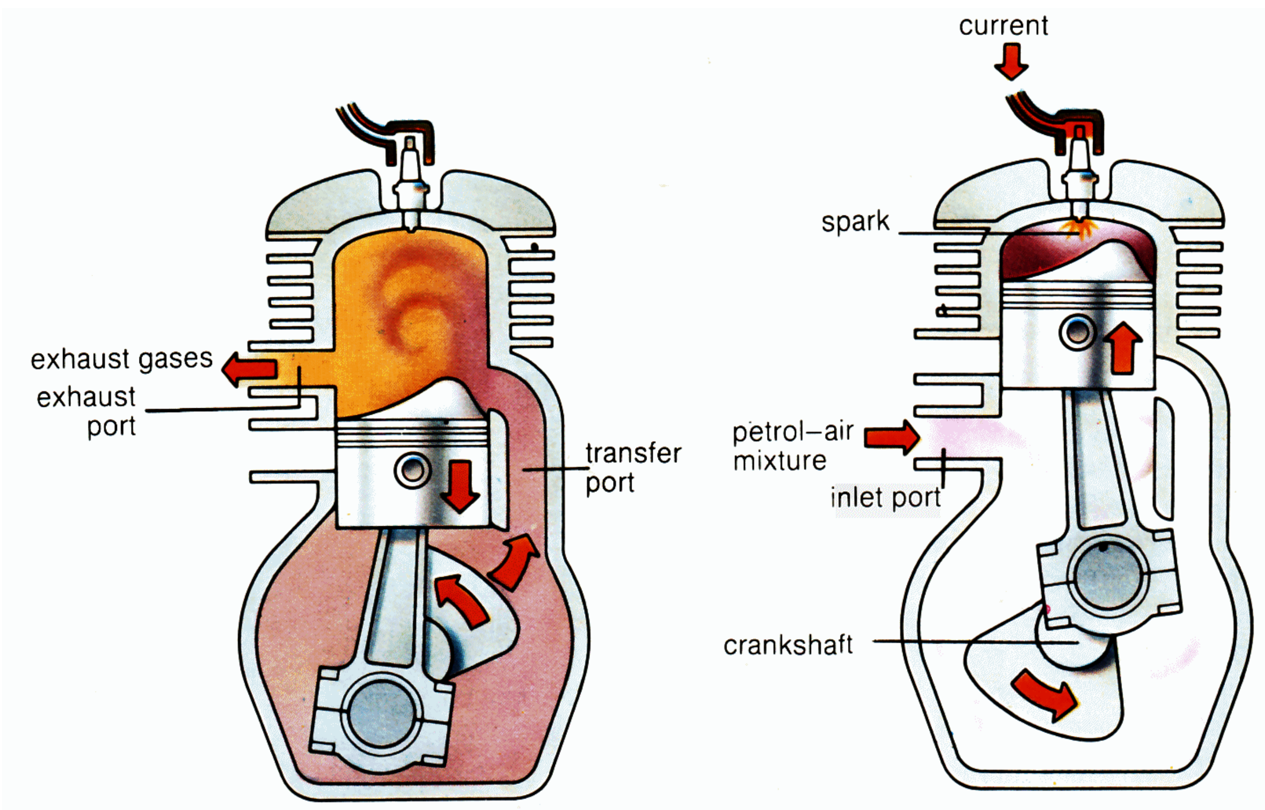

Figure 36: Schematic diagram of two stroke petrol engine

4.3 THEORY:

4.3.1 Spark Ignition Engine:

A **spark-ignition engine** is an internal combustion engine, generally a petrol engine, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. Spark-ignition engines are commonly referred to as "gasoline engines" in North America, and "petrol engines" in Britain and the rest of the world. However, these terms are not preferred, since spark-ignition engines can (and increasingly are) run on fuels other than petrol/gasoline, such as autogas (LPG), methanol, ethanol, bioethanol, compressed natural gas (CNG), hydrogen, and (in drag racing) nitromethane. They are widely used in passenger cars, motor cycles and other light vehicles. The range of Compression ratio for these engines varies from 4:1 to 10:1. Spark ignition engines are further classified on the basis of strokes i.e. the four stroke cycle and two stroke cycle

4.3.2 FOUR STROKE CYCLE PETROL ENGINE

In four stroke cycle engines the four events namely suction, compression, power and exhaust take place inside the engine cylinder. The four events are completed in four strokes of the piston (two revolutions of the crank shaft). This engine has got valves for controlling the inlet of charge and outlet of exhaust gases. The opening and closing of the valve is controlled by cams, fitted on camshaft. The camshaft is driven by crankshaft with the help of suitable gears or chains. The camshaft runs at half the speed of the crankshaft. The events taking place in four stroke SI engine are as follows: 1. Suction stroke 2. Compression stroke 3. Power stroke 4. Exhaust stroke

Suction stroke: During suction stroke inlet valve opens and the piston moves downward. Only a mixture of air and fuel are drawn inside the cylinder. The exhaust valve remains in closed position during this stroke. The pressure in the engine cylinder is less than atmospheric pressure during this stroke.

Compression stroke: During this stroke the piston moves upward. Both valves are in closed position. The charge taken in the cylinder is compressed by the upward movement of piston. A mixture of air and fuel is compressed in the cylinder; the mixture is ignited by a spark plug.

Power stroke: After ignition of fuel, tremendous amount of heat is generated, causing very high pressure in the cylinder which pushes the piston downward. The downward movement of the piston at this instant is called power stroke. The connecting rod transmits the power from piston to the crank shaft and crank shaft rotates. Mechanical work can be taped at the rotating crank shaft. Both valves remain closed during power stroke.

Exhaust stroke: During this stroke piston moves upward. Exhaust valve opens and exhaust gases go out through exhaust valves opening. All the burnt gases go out of the engine and the cylinder becomes ready to receive the fresh charge. During this stroke inlet valve remains closed. Thus it is found that out of four strokes, there is only one power stroke and three idle strokes in four stroke cycle engine. The power stroke supplies necessary momentum for useful work.

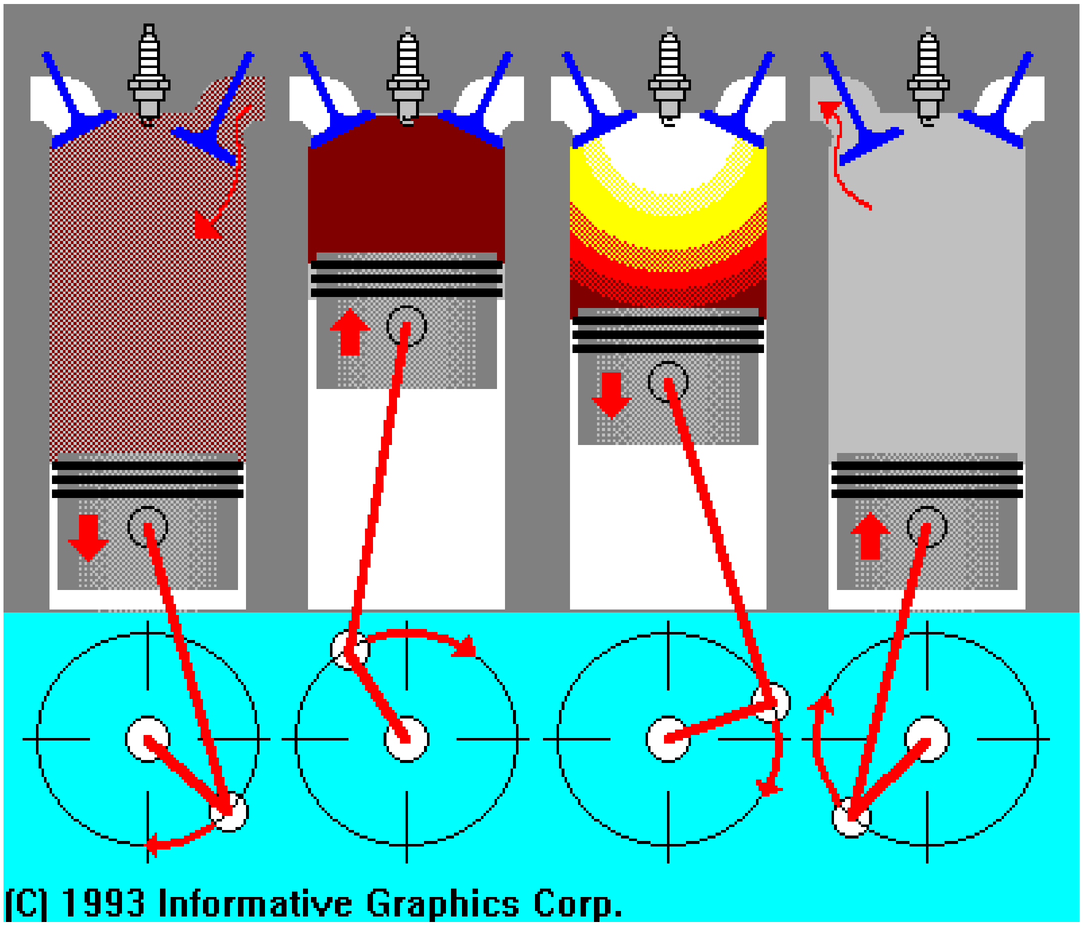

Figure 37: Intake, Compression, Power and exhaust stroke in a 4-Stroke SI engine

4.3.3 The Otto cycle: The ideal cycle for spark ignition engines

An **Otto cycle** is an idealized thermodynamic cycle that describes the functioning of a typical spark ignition piston engine. It is the thermodynamic cycle most commonly found in automobile engines. The Otto cycle is a description of what happens to a mass of gas as it is subjected to changes of pressure, temperature, volume, addition of heat, and removal of heat. The mass of gas that is subjected to those changes is called the system. The system, in this case, is defined to be the fluid (gas) within the cylinder. By describing the changes that take place within the system, it will also describe in inverse, the system's effect on the environment. In the case of the Otto cycle, the effect will be to produce enough network from the system so as to propel an automobile and its occupants in the environment.

The Otto cycle is constructed from: Top and bottom of the loop: a pair of quasi-parallel and isentropic processes (frictionless, adiabatic reversible).Left and right sides of the loop: a pair of parallel isochoric processes (constant volume). The isentropic process of compression or expansion implies that there will be no inefficiency (loss of mechanical energy), and there be no transfer of heat into or out of the system during that process. Hence the cylinder and piston are assumed impermeable to heat during that time. Work is performed on the system during the lower isentropic compression process. Heat flows into the Otto cycle through the left pressurizing process and some of it flows back out through the right depressurizing process. The summation of the work added to the system plus the heat added minus the heat removed yields the net mechanical work generated by the system.

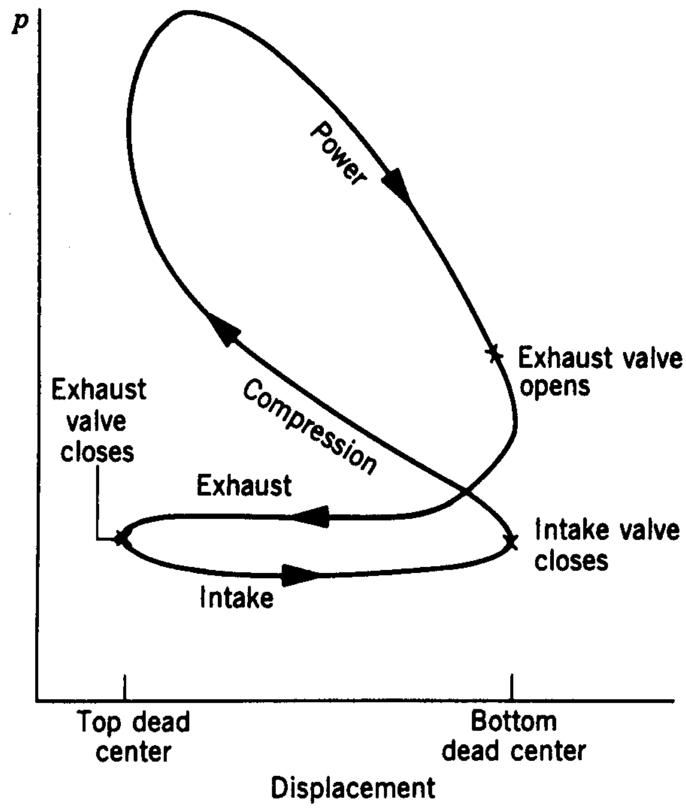

Figure 38: Real Otto cycle

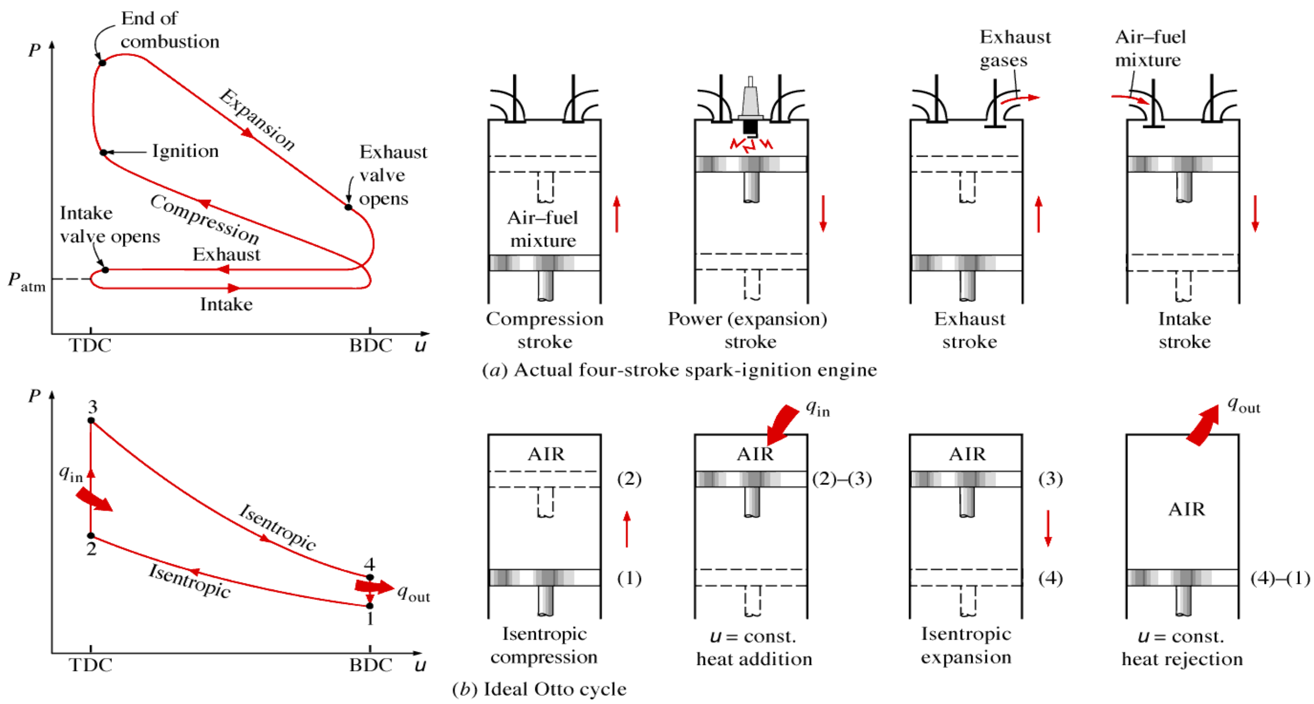

Figure 39: Real and Idealized Cycle

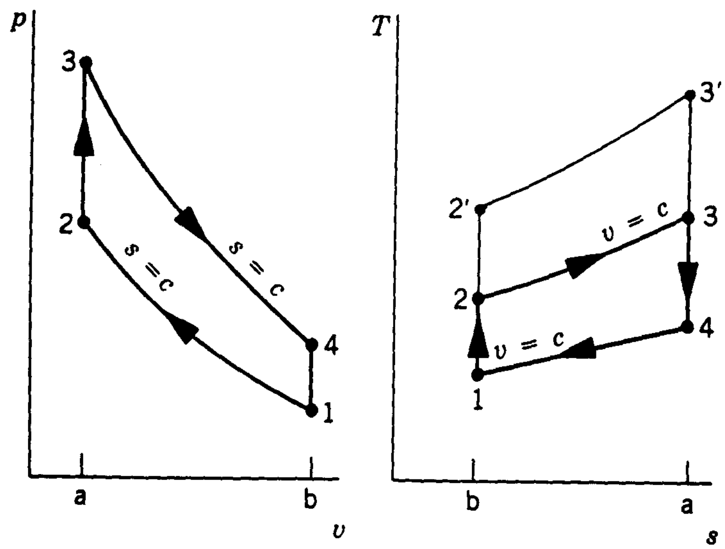

Figure 40: Idealized otto cycle

The processes are as follows;

- 1-2 - ADIABATIC COMPRESSION (ISENTROPIC)
- 2-3 - CONSTANT VOLUME HEAT ADDITION
- 3-4 - ADIABATIC EXPANSION (ISENTROPIC)
- 4-1 - CONSTANT VOLUME HEAT REJECTION

The Otto cycle consists of isentropic compression, heat addition at constant volume, isentropic expansion, and rejection of heat at constant volume. In the case of a four-stroke Otto cycle, technically there are two additional processes: one for the exhaust of waste heat and combustion products at constant pressure (isobaric), and one for the intake of cool oxygen-rich air also at constant pressure; however, these are often omitted in a simplified analysis. Even though those two processes are critical to the functioning of a real engine, wherein the details of heat transfer and combustion chemistry are relevant, for the simplified analysis of the thermodynamic cycle, it is more convenient to assume that all of the waste-heat is removed during a single volume change.

4.3.4 TWO STROKE CYCLE PETROL ENGINE

In two stroke cycle engines, the whole sequence of events i.e., suction, compression, power and exhaust are completed in two strokes of the piston i.e. one revolution of the crankshaft. There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is air tight in which the crankshaft rotates.

Upward stroke of the piston (Suction + Compression):

When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other. This traps the charge of air- fuel mixture drawn already in to the cylinder. Further upward movement of the piston compresses the charge and also uncovers the suction port. Now fresh mixture is drawn through this port into the crankcase. Just before the end of this stroke, the mixture in the cylinder is ignited by a spark plug. Thus, during this stroke both suction and compression events are completed.

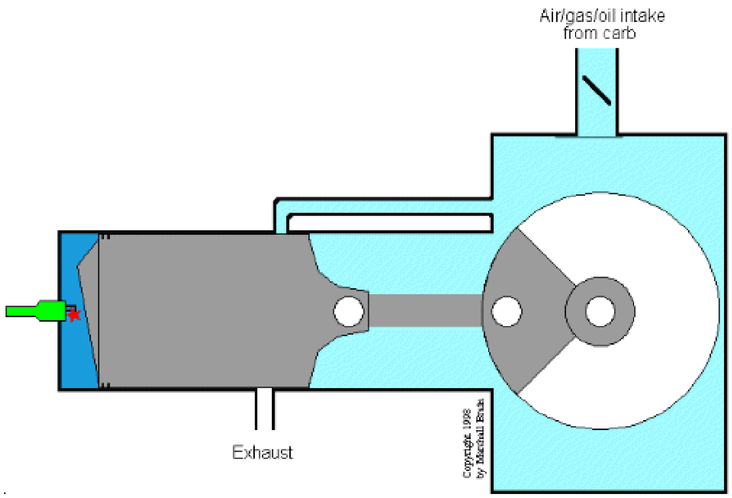

Figure 41: Upward stroke of the piston (Suction + Compression)

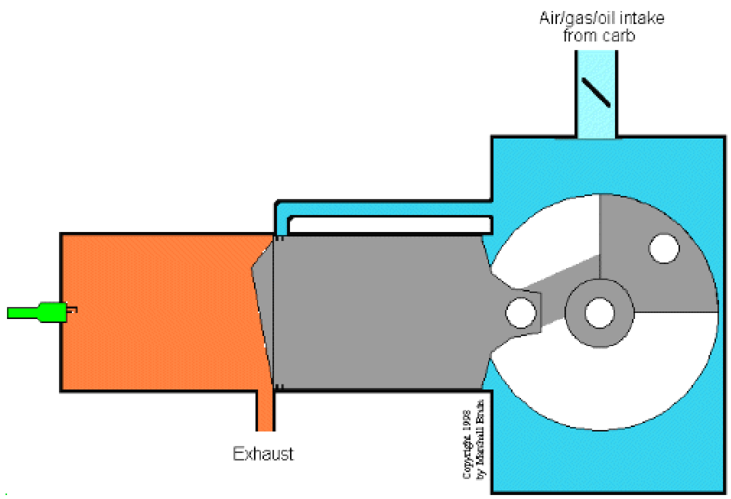

Figure 42: Ignition process

Downward stroke (Power + Exhaust):

Burning of the fuel rises the temperature and pressure of the gases which forces the piston to move down the cylinder. When the piston moves down, it closes the suction port, trapping the fresh charge drawn into the crankcase during the previous upward stroke. Further downward movement of the piston uncovers first the exhaust port and then the transfer port. Now fresh charge in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases . During the downward stroke of the piston power and exhaust events are completed.

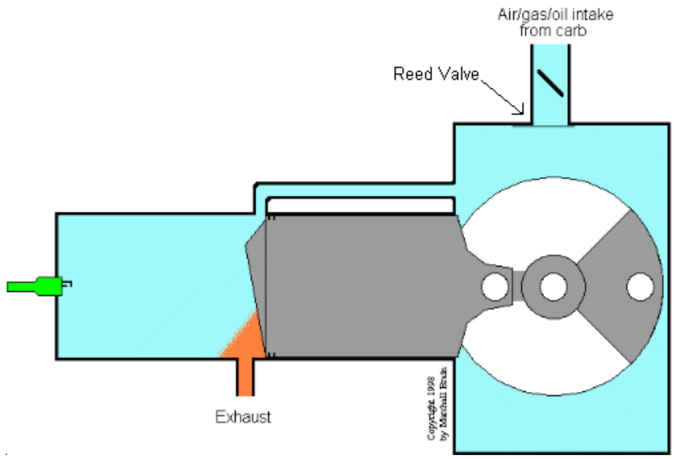

Figure 43: Downward stroke (Power + Exhaust)

Two-stroke petrol engines are preferred when mechanical simplicity, light weight, and high power-to-weight ratio are design priorities. With the traditional lubrication technique of mixing oil into the fuel, they also have the advantage of working in any orientation, as there is no oil reservoir dependent on gravity; this is an essential property for hand-held power tools such as chainsaws.

LAB SESSION NO: 05

THERMODYNAMICS FOR TECHNOLOGIST

COMPRESSION IGNITION ENGINE

OBJECTIVE

Study and experimental demonstration of compression ignition engine (four strokes & two strokes).

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE

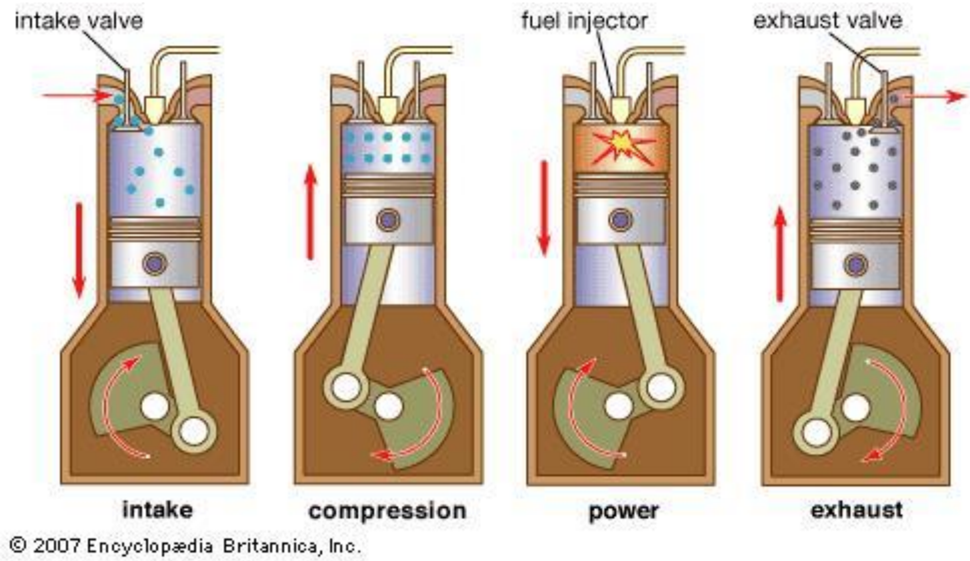

Figure 44: Four stroke diesel engine

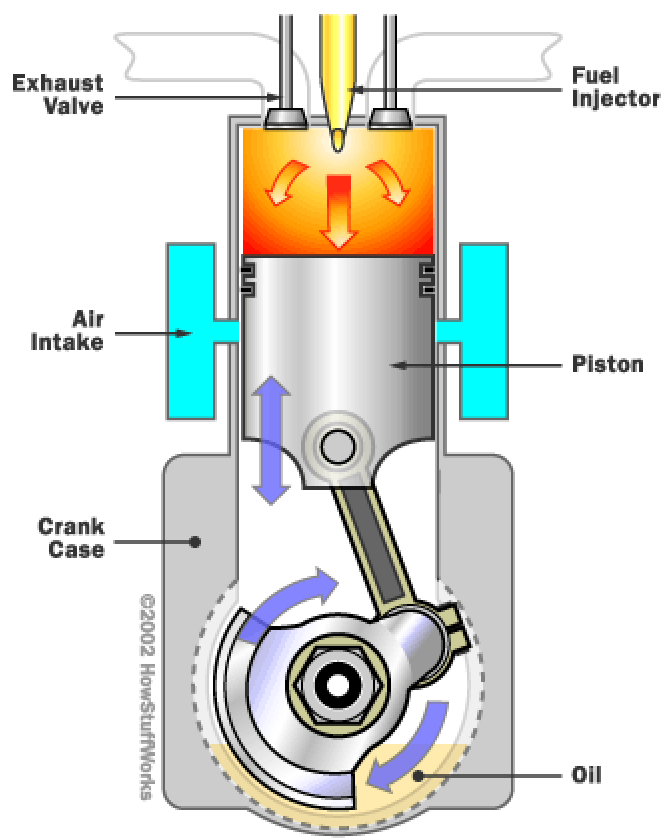

Figure 45: Two stroke diesel engine

5. OBJECTIVE

Study and experimental demonstration of compression ignition engine (four strokes and two strokes).

5.1 APPARATUS:

Cut models of four stroke and two stroke diesel engines.

5.2 SCHEMATIC DIAGRAM:

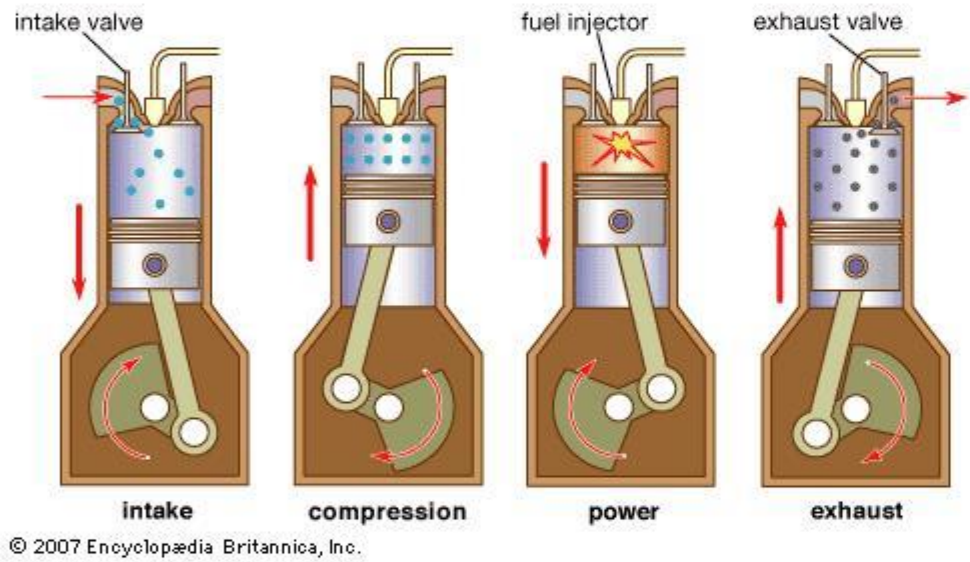

Figure 46: Schematic diagram of four stroke diesel engine

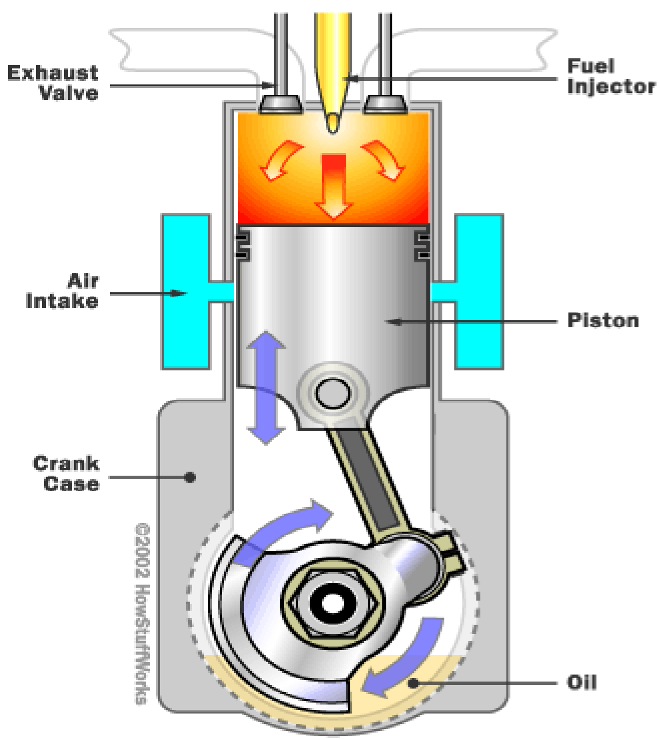

Figure 47: Schematic diagram of two stroke diesel engine

5.3 THEORY:

5.3.1 Spark Ignition Engine:

A **spark-ignition engine** is an internal combustion engine, generally a petrol engine, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. Spark-ignition engines are commonly referred to as "gasoline engines" in North America, and "petrol engines" in Britain and the rest of the world. However, these terms are not preferred, since spark-ignition engines can (and increasingly are) run on fuels other than petrol/gasoline, such as autogas (LPG), methanol, ethanol, bioethanol, compressed natural gas (CNG), hydrogen, and (in drag racing) nitromethane. They are widely used in passenger cars, motor cycles and other light vehicles. The range of Compression ratio for these engines varies from 4:1 to 10:1. Spark ignition engines are further classified on the basis of strokes i.e. the four stroke cycle and two stroke cycle

5.3.2 FOUR STROKE CYCLE PETROL ENGINE

Diesel engines have long been the source of power for heavy-duty trucks, trains, and ships. During the past few years, diesel engines have become more common as power sources for automobiles. The main advantage of diesel engines over gasoline engines is their good fuel efficiency. Diesel powered automobiles average about 25% more miles per gallon than gasoline powered automobiles. Diesel engines, however, must be made larger, stronger, and heavier than gasoline engines. They must withstand combustion pressures two to three times higher than those produced in gasoline engines. The added weight needed for strength reduces the acceleration of the automobile. A diesel engine of the same horsepower as a gasoline engine is larger. There are two basic types of diesel engines in use today: Four-stroke cycle & Two-stroke cycle. These engines differ in the number of piston strokes required to produce a power stroke. Their methods of intake and exhaust are also different.

In four stroke cycle engines the four events namely suction, compression, power and exhaust take place inside the engine cylinder. The four events are completed in four strokes of the piston (two revolutions of the crank shaft). This engine has got valves for controlling the inlet of charge and outlet of exhaust gases. The opening and closing of the valve is controlled by cams, fitted on camshaft. The camshaft is driven by crankshaft with the help of suitable gears or chains. The camshaft runs at half the speed of the crankshaft. The events taking place in four stroke CI engine are as follows: 1. Suction stroke 2. Compression stroke 3. Power stroke 4. Exhaust stroke

Four Stroke Diesel Engine: The cycle of operation in a four stroke diesel engine is completed in two revolutions of crankshaft or four strokes of piston using diesel oil as fuel. This engine works on diesel cycle. 1. Suction Stroke: Starting of engine is done by an electric motor or manually. In both cases the energy is supplied to the engine. In this stroke the inlet valve opens and the outlet valve remains closed. Piston moves from T.D.C. to B.D.C. and in this way a vacuum is created in the cylinder. This vacuum is filled by air alone and piston reaches to B.D.C.

2. Compression Stroke: Both valves are closed. This time piston moves from B.D.C. to T.D.C. Air is compressed in this stroke up to a compression ratio of 15:1 to 22:1 and a very high temperature is produced due to high pressure. The high temperature is the only cause of combustion of the fuel. The piston takes the power in this stroke from the flywheel. During this stroke the pressure and temperature attain a high value of 40 to 60 bar and 600º C to 700º C.

3. Working Stroke: At the end of compression stroke or when the piston reaches the T.D.C. position, a fine spray of diesel is injected in the cylinder through injector. The fuel burns by the heat of compressed air and due to its burning the power is produced. This power pushes the piston downward i.e. from T.D.C. to B.D.C. The excess energy of the piston is stored in the flywheel of the engine, which is further used for the remaining three strokes of the engine. The reciprocating motion of the piston is converted into the rotary motion of the crankshaft by connecting rod and crank. During expansion the pressure drops due to increase in volume of gases and absorption of heat by cylinder walls.

4. Exhaust Stroke: The exhaust valve begins to open when about 85% of the working stroke is completed. The force of piston coming from B.D.C. to T.D.C. forces the burnt gases into the exhaust manifold. Some of the gases are forced out due to higher pressure in the cylinder and the remaining gases are forced out by the piston. Some of the burnt gases are however left inside the clearance space. The exhaust valve closes shortly after T.D.C. The inlet valve opens slightly before the end of exhaust and in this way the cycle repeats.

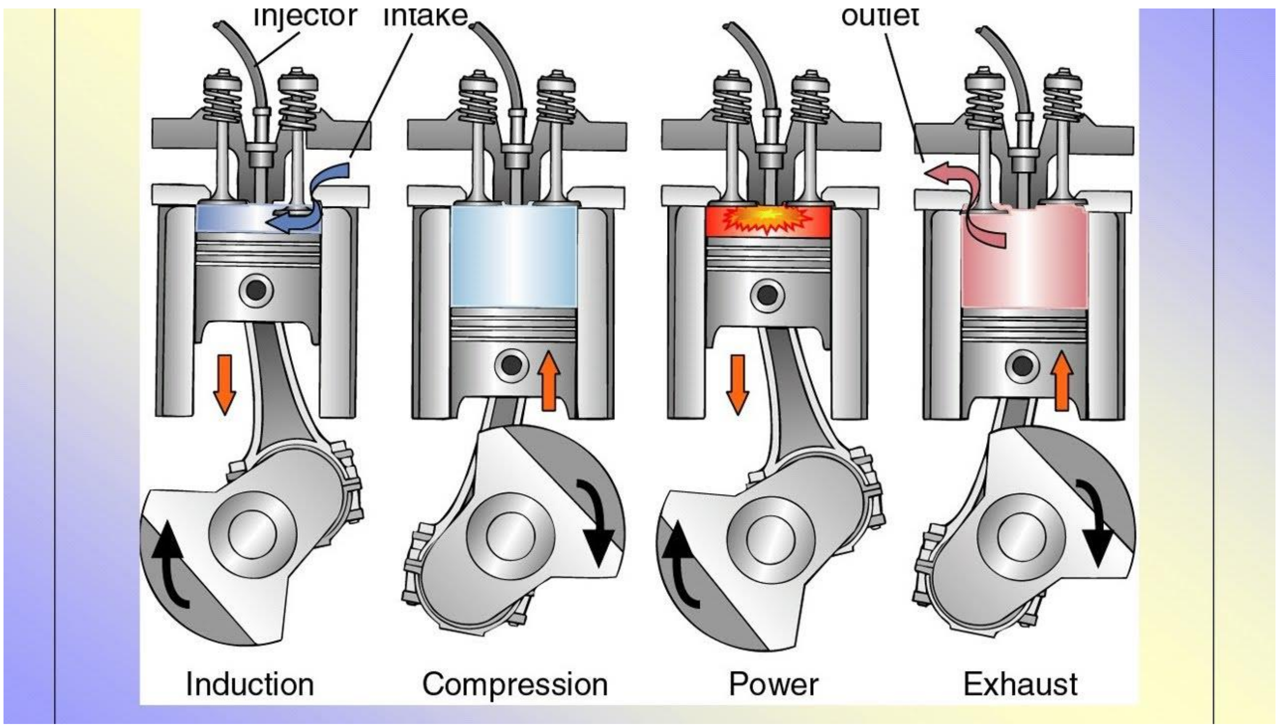

Figure 48: Intake, Compression, Power and exhaust stroke in a 4-Stroke CI engine

5.3.3 The Diesel cycle: The ideal cycle for compression ignition engines

The **Diesel cycle** is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected. This is in contrast to igniting the fuel-air mixture with a spark plug as in the Otto cycle (four-stroke/petrol) engine. Diesel engines are used n aircraft, automobiles, power generation, diesel-electric locomotives, and both surface ships and submarines. The Diesel cycle is assumed to have constant pressure during the initial part of the combustion phase. This is an idealized mathematical model: real physical diesels do have an increase in pressure during this period, but it is less pronounced than in the Otto cycle. In contrast, the idealized Otto cycle of a gasoline engine approximates a constant volume process during that phase.

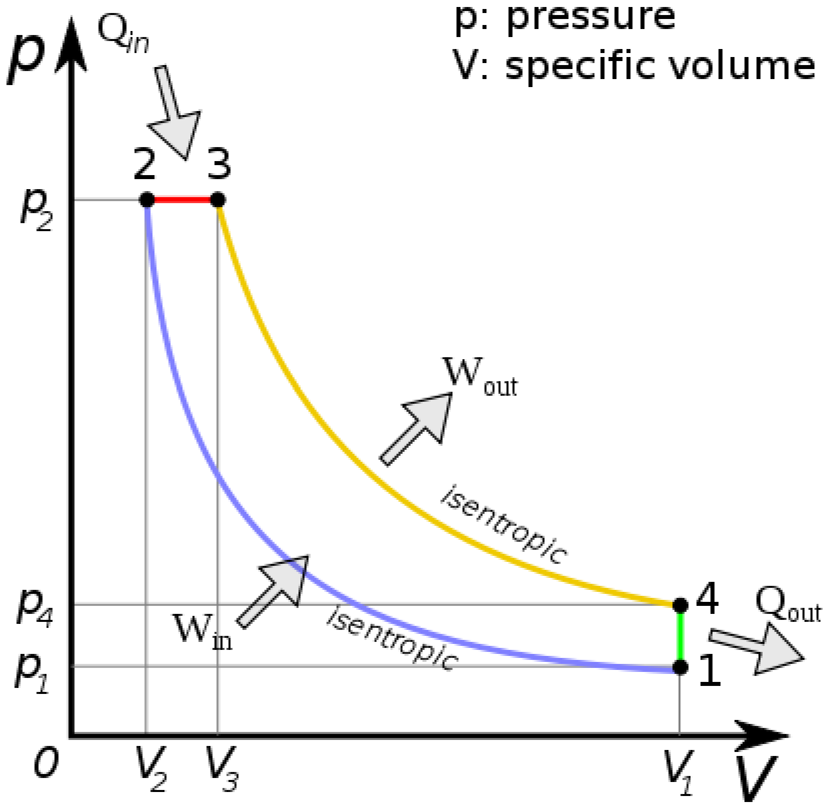

Figure 49: Ideal Cycle diagram for diesel engine

Air standard diesel cycle is a idealized cycle for diesel engines. It is as shown on P-v and T-s diagrams. The processes in the cycle are as follows:

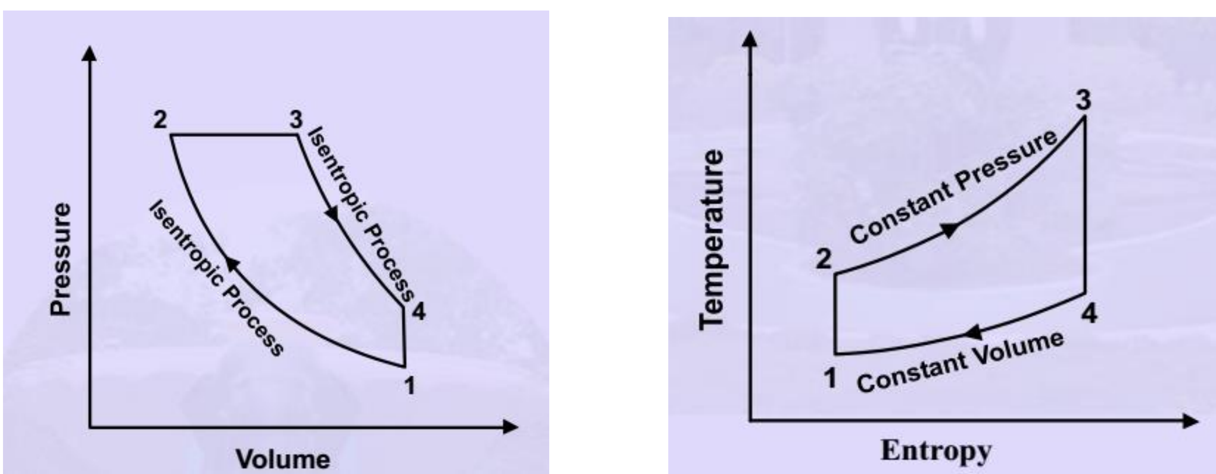

Figure 50: PV and TS diagram for a diesel engine

Process 1-2: Reversible adiabatic Compression.

Process 2-3: Constant pressure heat addition.

Process 3-5: Reversible adiabatic Compression.
Process 4-1: Constant volume heat rejection.

Four-stroke diesel engines are very similar to four-stroke gasoline engines. The piston travels from one end of the cylinder to the other four times during each cycle. The fuel is ignited at the beginning of the third stroke of each cycle. Intake air flows into each cylinder through intake valves in the cylinder head. Exhaust gases leave through exhaust valves. These valves operate the same way as the valves in four-stroke gasoline engines. On the intake stroke, atmospheric pressure pushes air into the cylinder through the intake valve. The exhaust stroke forces burned gases out through the exhaust valve. During the compression and power strokes, both valves are closed.

5.3.4 TWO STROKE CYCLE DIESEL ENGINE

In two stroke cycle engines, the whole sequence of events i.e., suction, compression, power and exhaust are completed in two strokes of the piston i.e. one revolution of the crankshaft. There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is air tight in which the crankshaft rotates.

Upward stroke of the piston (Suction + Compression):

When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other. This traps the air drawn already in to the cylinder. Further upward movement of the piston compresses the air and also uncovers the suction port. Now fresh air is drawn through this port into the crankcase. Just before the end of this stroke, the fuel is injected in the cylinder by fuel injector and combustion start. Thus, during this stroke both suction and compression events are completed.

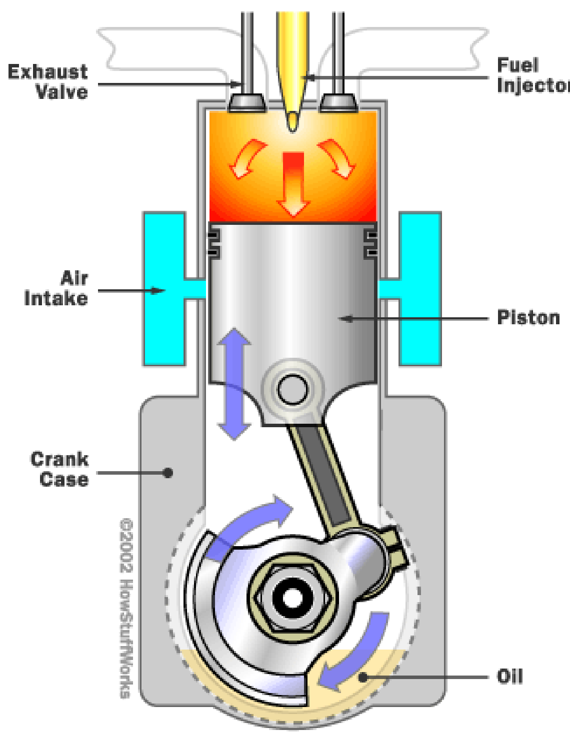

Figure 51: Two stroke diesel engine

Downward stroke (Power + Exhaust):

Burning of the fuel rises the temperature and pressure of the gases which forces the piston to move down the cylinder. When the piston moves down, it closes the suction port, trapping the fresh air drawn into the crankcase during the previous upward stroke. Further downward movement of the piston uncovers first the exhaust port and then the transfer port. Now fresh air in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases. During the downward stroke of the piston power and exhaust events are completed.

The diesel engine looks much like the gasoline engine. The operations of the mechanical systems are also similar in both engines. The piston and crankshaft assembly, the valve assembly, the lubrication system, and the cooling system operate in the same way. However, diesel systems are built stronger to withstand higher combustion pressures. The two major differences between gasoline and diesel engines are the way that fuel is supplied to the cylinders and the way the fuel is ignited. The diesel engine does not need an ignition system. Compression heat ignites the fuel in the cylinder. A special fuel system supplies fuel to the cylinder. Diesel fuel systems are very different from gasoline fuel systems.

5.3.5 Fuel System

In a gasoline engine, fuel is mixed with air in the carburetor or in the intake manifold. Diesel engines do not have carburetors. Only air flows into the combustion chamber through the intake manifold. Each intake stroke completely fills the cylinder with air. Special devices inject fuel into the air inside the cylinder. Engine power is controlled by metering the amount of fuel injected into the cylinders. At idle, only a small amount of fuel is injected into each cylinder. The ratio of air to fuel may be 40 to 1. The ratio in gasoline engines at idle is about 18 to 1. As power needs increase, the amount of fuel injected increases. However the amount of air remains the same. Therefore, the ratio of air to fuel decreases. The intake stroke always takes in enough air to burn all the fuel injected during full-load operation.

5.3.6 Fuel-Injection Systems

The main components in a diesel fuel-injection system are the fuel-injection pump and the fuel injectors. The job of the fuel injectors is to inject a measured amount of fuel into the combustion chamber. When pressure is applied to the fuel, the injector opens and sprays fuel into the cylinder. Combustion begins immediately. The fuel-injection pump produces the necessary high fuel pressure. On injection, diesel fuel must be under enough pressure to offset the pressure inside the combustion chamber (about 1000 psi during combustion). If the fuel pressure were not at least as high as the pressure in the combustion chamber during combustion, the fuel would not inject. Instead, pressure would leak from the combustion chamber into the injector nozzle. The injection pump has two other functions. It must regulate the amount of fuel directed to the cylinder. It must also control the timing of the fuel injection. Engine power depends on the amount of fuel supplied to the cylinders. The time at which injectors spray fuel into the cylinders is just as important. The injection pump controls this timing. It makes sure that the injectors spray fuel just before TDC (top dead center) of the compression stroke. By the time the fuel ignites, the piston will have started its downward motion.

5.3.7 Fuel Injection Arrangements

The injection pump and injectors may not be completely separate. These two parts can be arranged in three different ways.

1. Multiple-Plunger System
2. Unit Injector System
3. Distributor System

Multiple-Plunger System

In this system, there is a separate pumping unit (plunger) and a separate injector for each cylinder. The plungers are all part of the fuel-injection pump. A camshaft inside the pump controls the action of the plungers. Fuel lines connect the plungers to the injectors. The amount of fuel to be injected is controlled at the fuel-injection pump.

Unit Injector System

In this system, the injection pump and injector are combined into one unit and are driven by the overhead camshaft. The plunger is a part of the injector. Pressurization, timing, and metering of the fuel all take place in the unit injector. An engine with this system has one unit injector for each cylinder.

Distributor System

In this system, a single injection pump supplies fuel to a distributor. The distributor directs fuel to the injectors in the right firing order. The metering of fuel is done at the pump.

5.3.8 Fuel-Injection System Operation

Diesel engines use several different injection systems. Their operating principles are the same. The multiple-plunger system contains both high- and low-pressure fuel systems. The low-pressure system consists of a fuel pump, lines, and filters, similar to the parts in a gasoline system. These parts deliver fuel from the tank to the fuel-injection pump. The high-pressure system consists of the fuel-injection pump and the injectors. These parts supply fuel to the cylinders.

5.3.9 Glow Plugs

Because there is no spark to ignite the fuel, diesel engines can be hard to start. This is especially true in cold weather. For improved starting, diesels are often equipped with glow plugs. Glow plugs have a small wire element that gets red-hot when connected to an electrical source. Each cylinder has a glow plug. When the diesel is to be started, current from the battery heats the glow plugs. The glow plugs then heat the fuel as it enters the cylinders. This preheating of the fuel lowers its ignition point to improve starting.

5.3.10 Air Blowers and Turbochargers

Two-stroke diesel engines require an air blower. This device forces air into the cylinder and drives out the exhaust gases. When the piston reaches the bottom of the power stroke, the air inlet ports are uncovered. The blower forces air into the cylinder. The air drives the burned gases out the exhaust valve and fills the combustion chamber. Some modern four-stroke diesel engines use a special kind of blower called a turbocharger. A turbocharger consists of an air impellor and an exhaust turbine connected to a shaft. High-pressure exhaust gases leaving the engine drive the turbine. The turbine, in turn, drives the air impellor. The air impellor forces air into the combustion chamber at a pressure higher than atmospheric pressure. The action puts more air into the cylinder. This provides higher compression for greater power output.

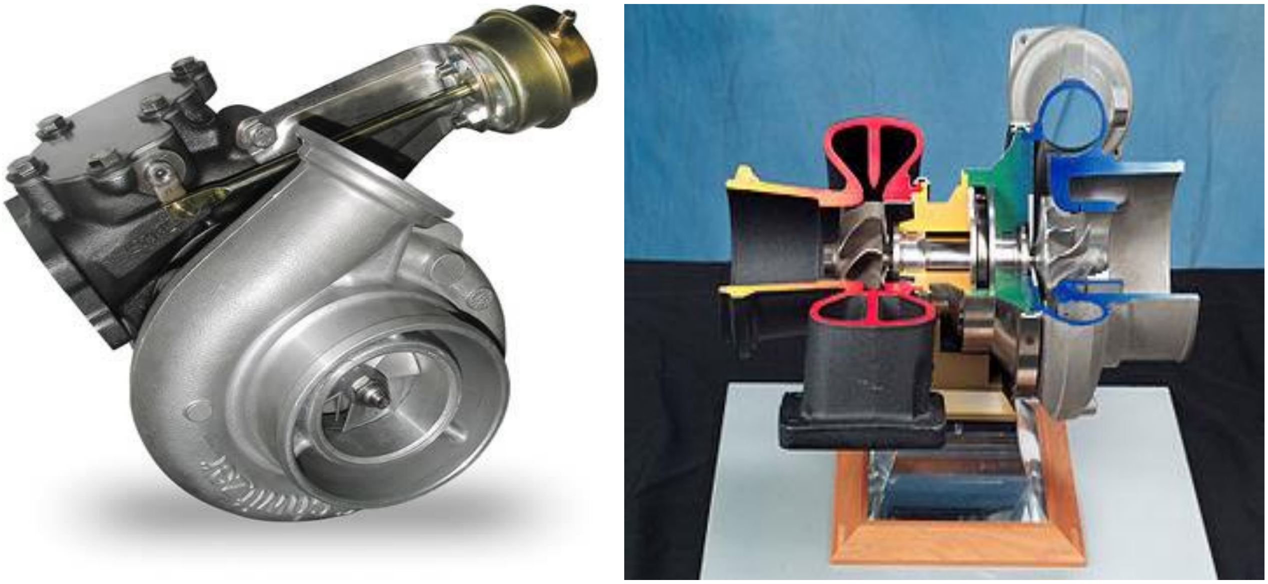

Figure 52: Turbocharger used in CI engines

A turbocharger, or colloquially turbo, is a turbine-driven forced induction device that increases an internal combustion engine’s efficiency and power output by forcing extra air into the combustion chamber. This improvement over a naturally aspirated engine's power output is due to the fact that the compressor can force more air and proportionately more fuel into the combustion chamber than atmospheric pressure (and for that matter, ram air intakes) alone. Turbochargers were originally known as turbo superchargers when all forced induction devices were classified as superchargers. Nowadays the term "supercharger" is usually applied only to mechanically driven forced induction devices. The key difference between a turbocharger and a conventional supercharger is that a supercharger is mechanically driven by the engine, often through a belt connected to the crankshaft, whereas a turbocharger is powered by a turbine driven by the engine's exhaust gas. Compared to a mechanically driven supercharger, turbochargers tend to be more efficient, but less responsive. Twin charger refers to an engine with both a supercharger and a turbocharger. Turbochargers are commonly used on truck, car, train, aircraft, and construction equipment engines. They are most often used with Otto cycle and Diesel cycle internal combustion engines. They have also been found useful in automotive fuel cells.

Components of a turbo charger:

1. The turbine, which is almost always a radial inflow turbine.
2. The compressor, which is centrifugal compressor.
3. The center housing/hub rotating assembly.

Turbine: Energy provided for turbine work is converted from enthalpy and kinetic energy of gas. The turbine housings direct the gas flow through turbine as it spins up-to 250,000 rpm. The size and shape can dictate some performance characteristics of overall turbocharger.

Compressor: The compressor increases mass of intake air entering the combustion chamber. The compressor is made up of an impeller. A diffuser and voltage housing. The operating range of compressor is described by compressor map.

Center housing/hub rotating assembly: The center hub rotating assembly houses the shaft that connects the compressor impeller and turbine. It also contains a bearing system to suspend the shaft, allowing it to rotate it at very high speed with minimal friction. For instance, in automotive applications the "CHRA" typically uses a thrust bearing or ball bearing lubricated by a constant supply of pressurized engine oil. The "CHRA" may be considered "water-cooled" by having an entry and exit point for engine coolant. Water-cooled models use engine coolant to keep lubricating oil cooler, avoiding possible oil coking from extreme heat in turbine. The development of air foil bearings removed the risk.

LAB SESSION NO: 06

REFRIGERATION AND AIR CONDITIONING LABORATORY

MECHANICAL HEAT PUMP

OBJECTIVE

To determine the Coefficient of Performance of heat Pump and Production of Heat Pump performance curves based on the R134a properties at a variety of Evaporating and Condensing temperatures. (An application of first and second law of thermodynamics)

DEPARTMENT OF MECHANICAL ENGINEERING &TECHNOLOGY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY LAHORE

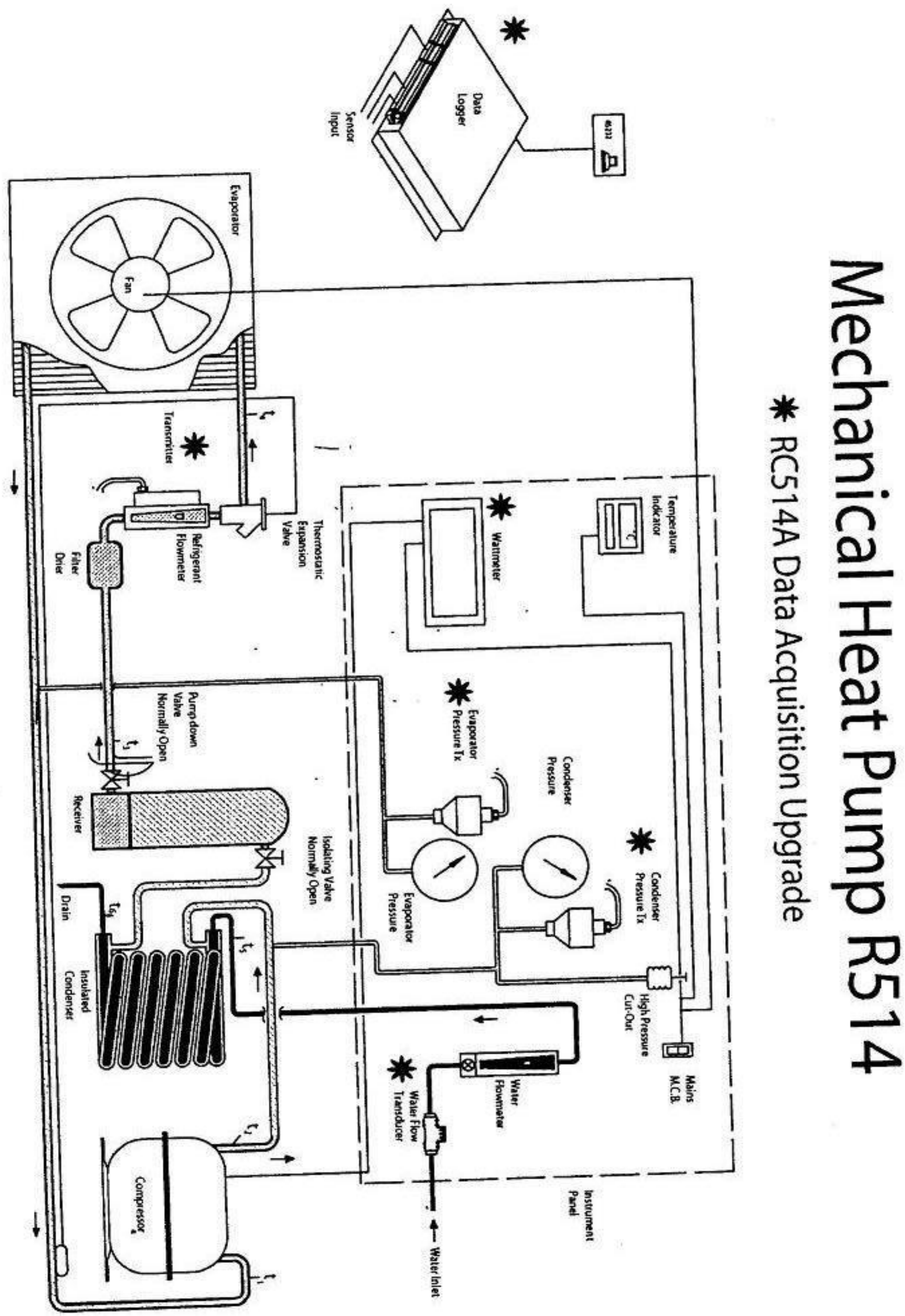

Figure 53: Schematic Diagram of Mechanical Heat Pump

6. OBJECTIVE

To determine the Coefficient of Performance of heat Pump and Production of Heat Pump performance curves based on the R134a properties at a variety of Evaporating and Condensing temperatures. (An application of first and second law of thermodynamics)

6.1 APPARATUS:

Mechanical Heat Pump

6.2 SCHEMATIC DIAGRAM:

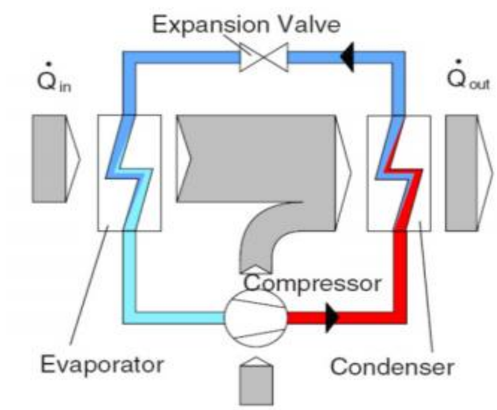

Figure 53: Vapor Compression Refrigeration Cycle

6.3 THEORY:

Schematic of a vapor compression refrigeration cycle is shown in Fig. 1; this cycle has the following component:

- A compressor which compresses the vapor of refrigerant. It consumes electrical power and provides the required mechanical energy (work) to the system.
- The condenser that absorbs heat (at constant pressure) from the hot and high pressure refrigerant and transfers it to the high temperature source.
- An expansion (throttling) valve that expands the liquid working medium during a constant enthalpy process.
- An evaporator facilitates the evaporation of the refrigerant while it absorbs heat from the low temperature reservoir.

The pressure-enthalpy diagram for an ideal refrigeration cycle is shown in the Fig. 1.2 (a), which includes the following processes:

- 1-2: Isentropic compression of the refrigerant from saturated vapour to superheated vapour (adiabatic process).
- 2-2’: Isobaric heat transfer (cooling) to the condensation temperature,
- 2’-3: Isobaric condensation, releasing the condensation enthalpy,

- 3-4: Isenthalpic expansion from saturated liquid to mixture of gas and liquid,
- 4-1: Isobaric evaporation, absorption of the evaporation enthalpy,

As shown in Fig. 55 (b), the key difference between the real cyclic process and the ideal cyclic process is that in reality the compression process is not isentropic; process 1'-2' in Fig. 55. Thus, in actual cycle more work must be expended at the compressor to achieve the same final pressure as in the ideal cycle. In addition, in the actual cycle superheating of the refrigerant is necessary prior to compression (process 1-1' in Fig. 55) to avoid the possibility of the entry of liquid droplets into the compressor. Otherwise the compressor blades would be damaged by the impact of liquid droplets. By means of liquid sub-cooling (3-3') the vapor portion in the mixture is reduced (compare state 4 with 4') and more heat can be transferred in the evaporator. Hence, more evaporation heat is absorbed (4'- 1').

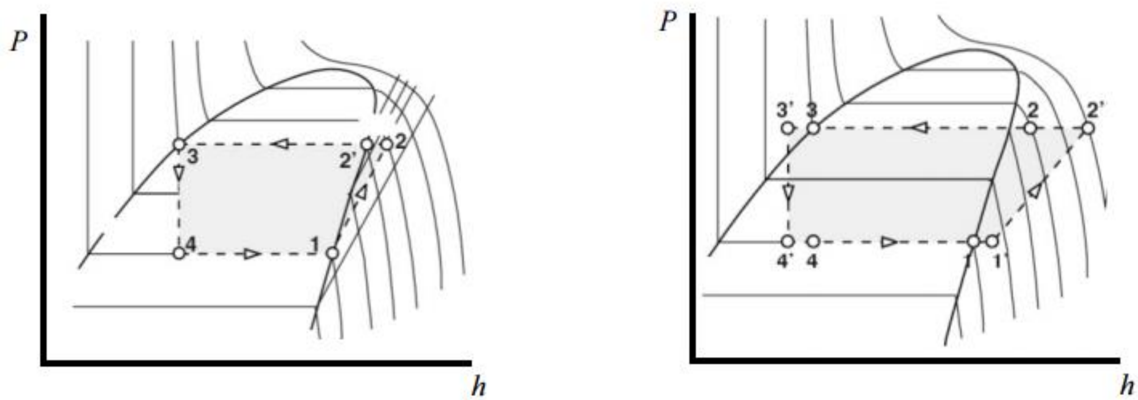

Figure 54: Pressure-enthalpy diagram of an (a) ideal refrigeration cycle (b) real refrigeration cycle

6.4 PROCEDURE:

Switch on the vapor-compression refrigeration apparatus after taking care of all necessary precautions. Allow running of the apparatus for a while so that the readings shown become stable. Change the condenser water flow rate using the knob provided, for each set of readings. Insert the values in the table of observations.

6.5 CALCULATIONS:

Work input rate across Compressor $w_{com} = 4500 / X$ (I)

Heat Transfer in Condenser $q_{con} = m_r \times (h_2 - h_3)$ (II)

Heat Transfer to water $= m_w C_p (T_6 - T_5)$ (III)

Heat Transfer in Evaporator $q_{evap} = m_r \times (h_1 - h_4)$ (IV)

Coefficient of Performance $COP = q_{con} / w_{com}$ (V)

Table 5:Observations and calculations of operating parameters of Mechanical Heat Pump

Sr. No	Pressure at 1 kN/m^{-2}	Pressure at 2 kN/m^{-2}	Temp at 1 (°C)	Temp at 2 (°C)	Temp at 3 (°C)	Temp at 4 (°C)	Ref. flow rate (g/s^{-1})	Time Per rev. (s)	Cond. Water Temps. In/Out		H.T. In Evap (W)	H.T. in Cond (W)	Comp Input (W)	COP
	P_1	P_2	T_1	T_2	T_3	T_4	m_{ref}	X	T_6	T_5	q_{evap}	q_{cond}	w_{com}	
1														
2														
3														
4														

6.6 SPECIMEN CALCULATION:_ (for 4th set of reading)

Draw the state points on p-h diagram as follows:

(1) Is located by the intersection of P_1 = ____________ and T_1= ________
(2) Is located by the intersection of P_2 = ____________ and T_2= ________
(3) Is located by the intersection of P_3 = ____________ and T_3= ________
(4) Is located by the intersection of T_4 = ____________ and $h_3=h_4$

The following readings were taken from p-h diagram

h_1 = h_2 = $h_3 = h_4$ =

Work input rate across Compressor $w_{com} = 4500 / X$ (I)

w_{com} =

w_{com} =

Heat Transfer in Condenser $q_{con} = m_r \times (h_2 - h_3)$ (II)

q_{con} =

q_{con} =

Heat Transfer in Evaporator $q_{evap} = m_r \times (h_1 - h_4)$ (III)

q_{evap} =

q_{evap} =

Coefficient of Performance COP $= w_{com} / q_{con}$ (IV)

COP =

COP =

PLOTS: Draw the following plots:

2- COP Vs Condenser water outlet temperature
3- Compressor power input rate Vs condenser water outlet temperature
4- Heat output rate Vs condenser water outlet temperature
5- Heat Transfer in Evaporator Vs condenser water outlet temperature

6.7 COMMENTS:

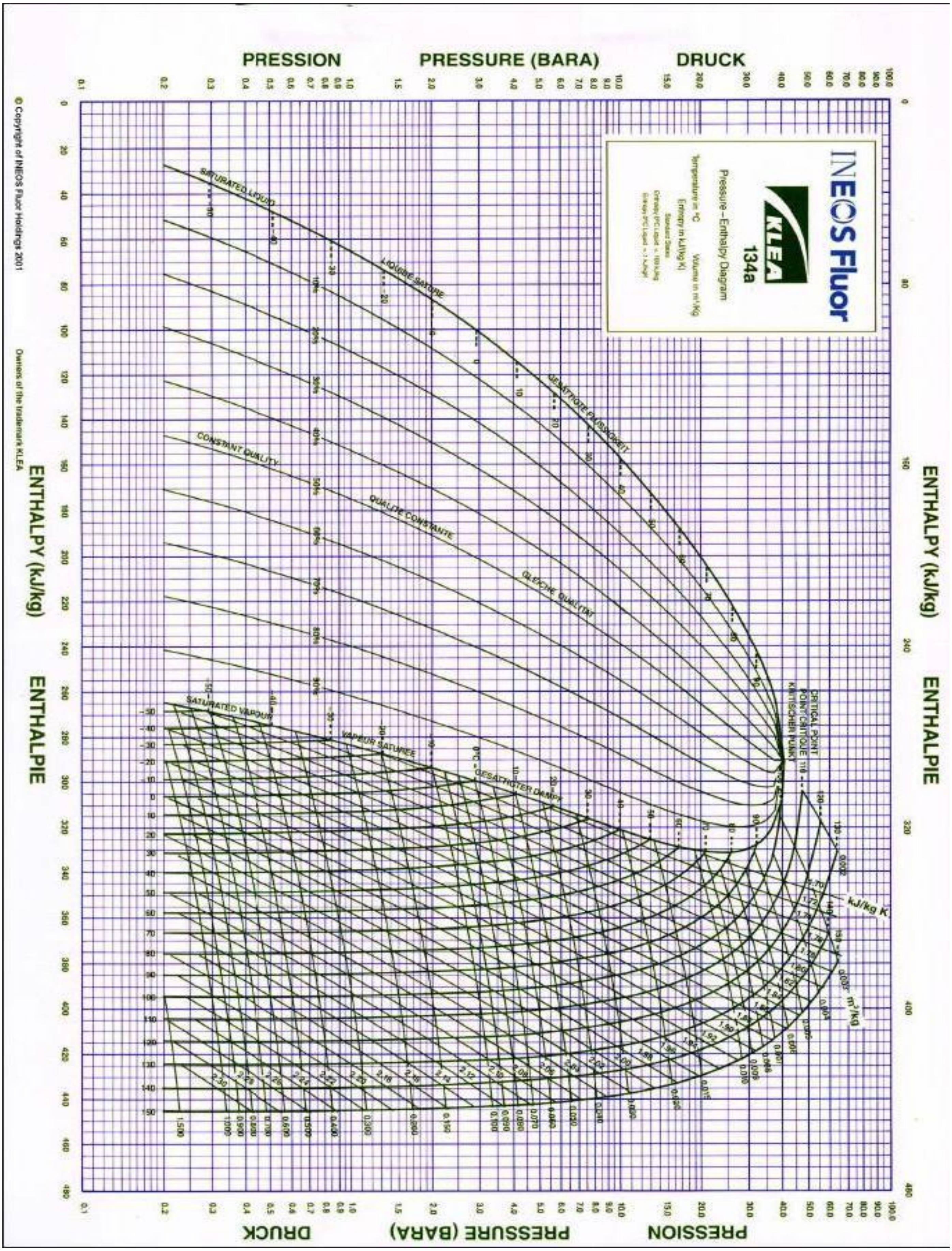

Figure 55: P-h Chart for Refrigerant R134a

Table 6: Observations and calculations of all operating parameters of Mechanical Heat Pump

Atmospheric Pressure = _____________mm Hg

Atmospheric Temperature =______________˚C

No. of obs.	Test	1	2	3	4	5	6
Time 1 Rev. of meter	$\frac{x}{s}$						
Mass flow rate	$\frac{\dot{m}_r}{gs^{-1}}$						
Compressor suction (evaporator) pressure	$\frac{P1}{kNm^{-2}}$						
Compressor delivery (condenser) pressure	$\frac{P2}{kNm^{-2}}$						
Compressor suction temperature	$\frac{T1}{°C}$						
Compressor delivery temperature	$\frac{T2}{°C}$						
Condenser outlet temperature	$\frac{T3}{°C}$						
Evaporator inlet temperature	$\frac{T4}{°C}$						
Mass flow rate	$\frac{\dot{m}_w}{gs^{-1}}$						
Condenser inlet temperature	$\frac{T5}{°C}$						
Condenser outlet temperature	$\frac{T6}{°C}$						