Systems In Mechanical Engineering

Unit no.2

THERMAL ENGINEERING

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Thermodynamics

- **A branch of Engg. Science which deals with energy transfer & its effect on physical properties of substances.**
- *Thermodynamics* is the science that primarily deals with energy
- Energy => Ability to cause Change
- Science that deals with heat and work and properties of substance that bear a relation with heat and work

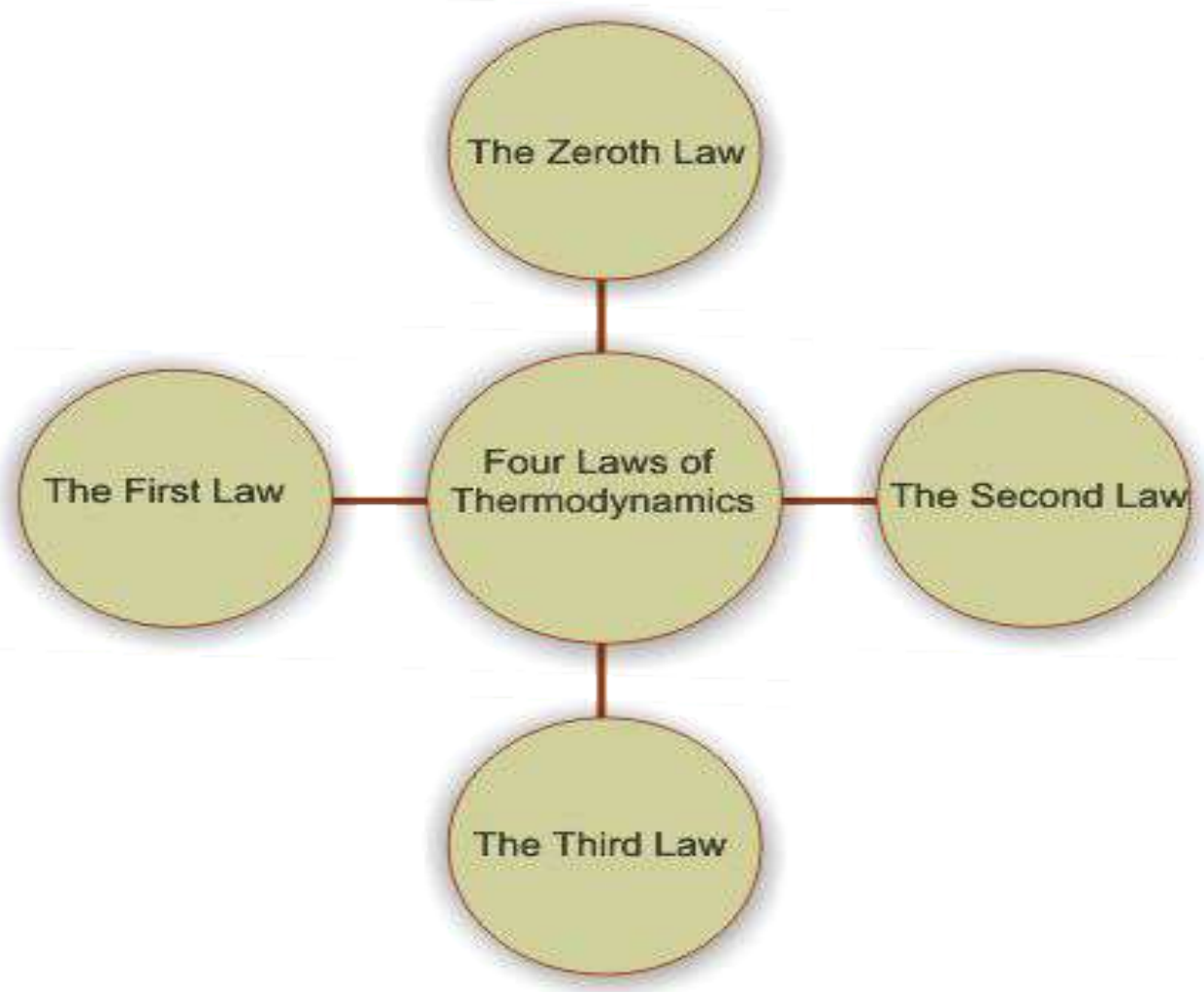
Areas of Application of Thermodynamics:

1)All natural processes are governed by the principles of thermodynamics.

2)engineering devices are typically designed based on the principles of thermodynamics.

3)Automotive engines, Turbines, Compressors, Pumps, Fossil and Nuclear Power Plants, Propulsion systems for the Aircrafts, Separation and Liquefaction Plant, Refrigeration, Air-conditioning and Heating Devices.

Thermodynamic ,basically depends on four laws – Zeroth ,first, second and third law of thermodynamic.



Thermodynamic Systems

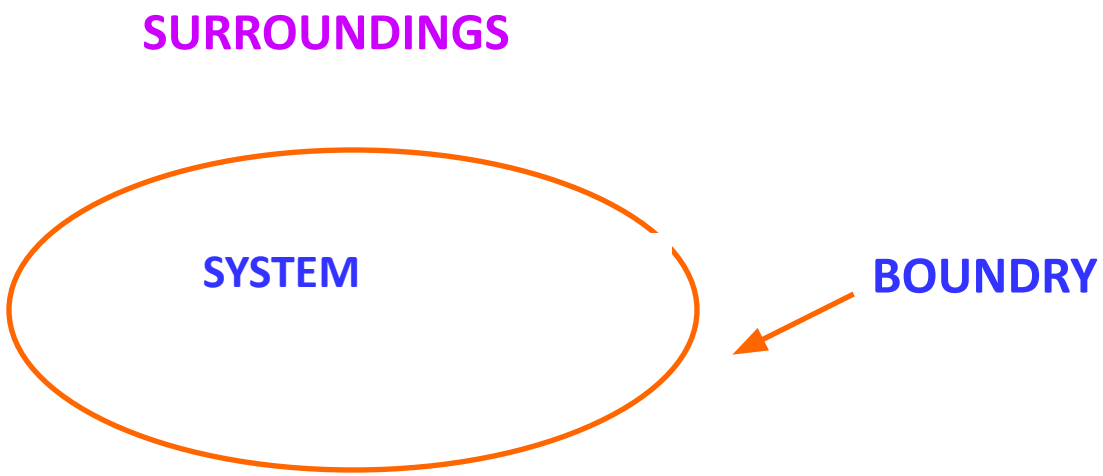
- Thermodynamics *system* is defined as a *quantity of matter or region in space chosen for study.*

- The mass or region outside the system is called the *surroundings*

- ***System boundary*** is the real and imaginary surface that separates the system from the surrounding. *Boundary* can be fixed or movable

- May be *closed* or *open*

Thermodynamic system is a quantity of matter or region in space chosen for study.

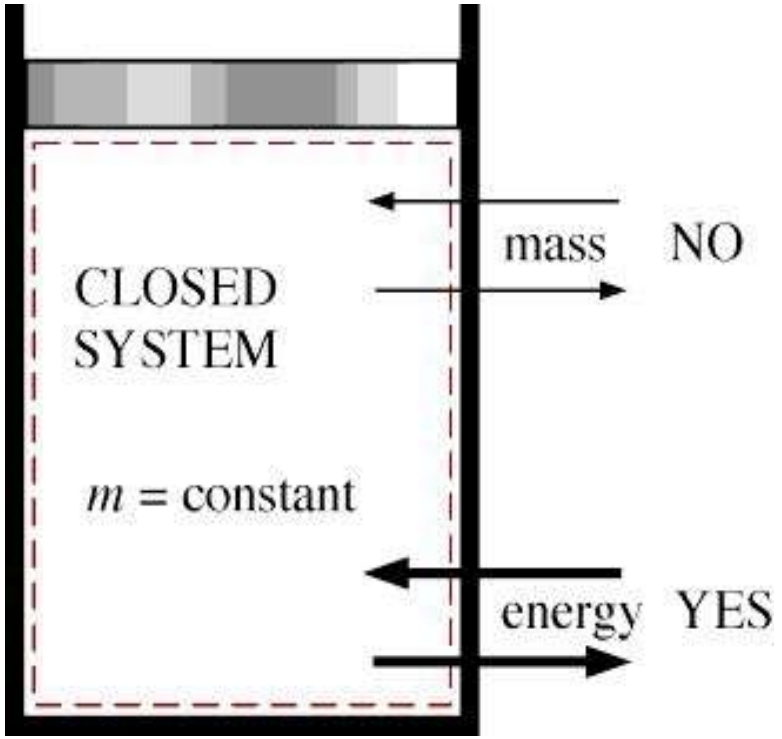


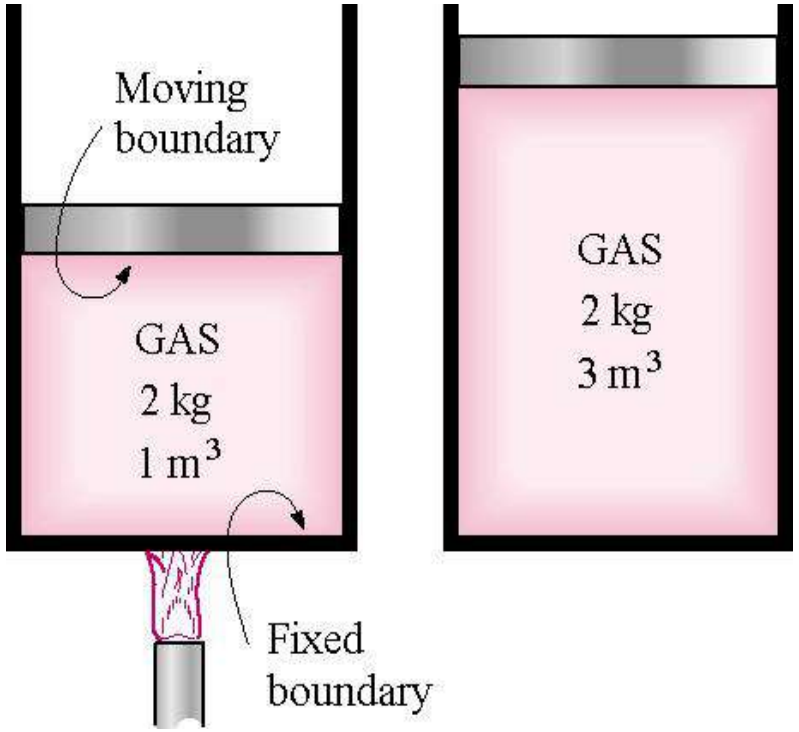
Closed System/Control Mass

- A system of fixed mass is called a *closed system*, or *control mass*
- The *closed system boundary* does not have to be fixed
- No mass can cross the *closed system* boundary
- Energy in the form of *heat* and *work* can cross the *closed system boundary*.

Closed System/Control Mass

E.g hot water stored in tank ,cylinder with movable piston.





Energy, not mass, crosses closed-system boundaries

Closed system with moving boundary

Open System / Control Volume

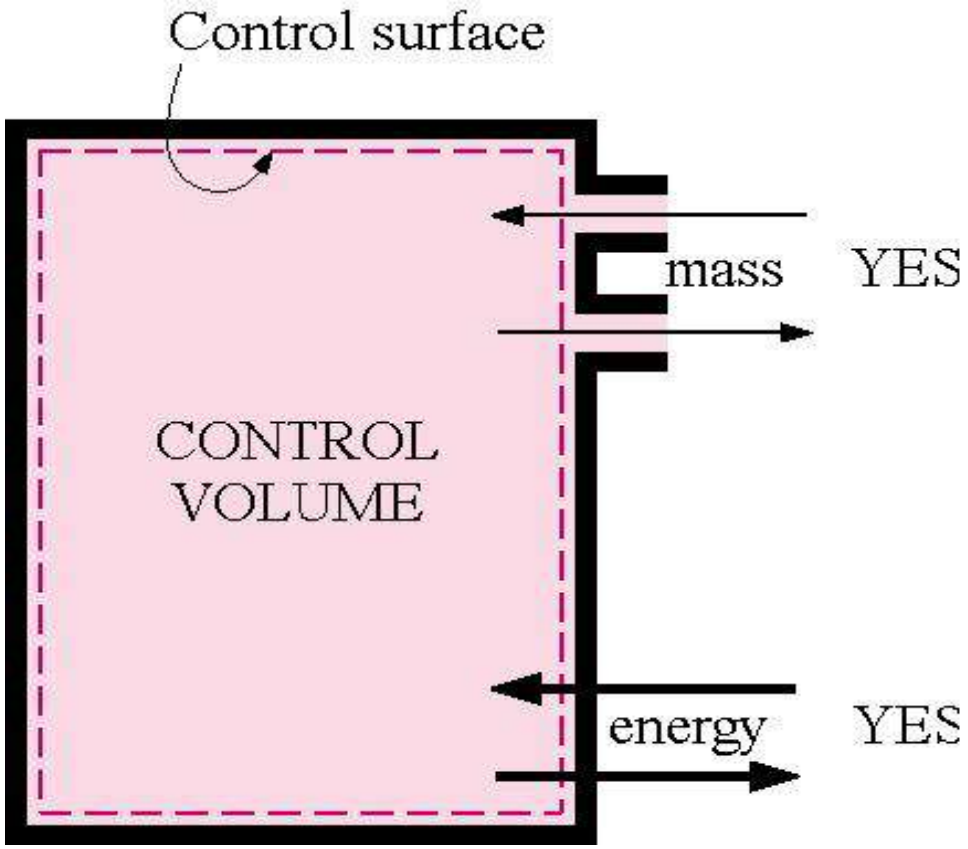
- **A system that involves mass transfer & energy transfer across its boundaries is called an *open system*, or *control volume***

- The boundaries of a *control volume* is called *control boundaries* and is fixed in shape and position

- Energy in the form of *heat* and *work* as well as mass can cross the *control boundaries*

Open System / Control Volume

Mass and Energy Cross Control Volume Boundaries
e.g. I.C. Engine, air compressor, gas turbine



Isolated System

no interaction between system & surrounding

no mass & energy transfer

Eg:- Thermas

Thermodynamic Properties

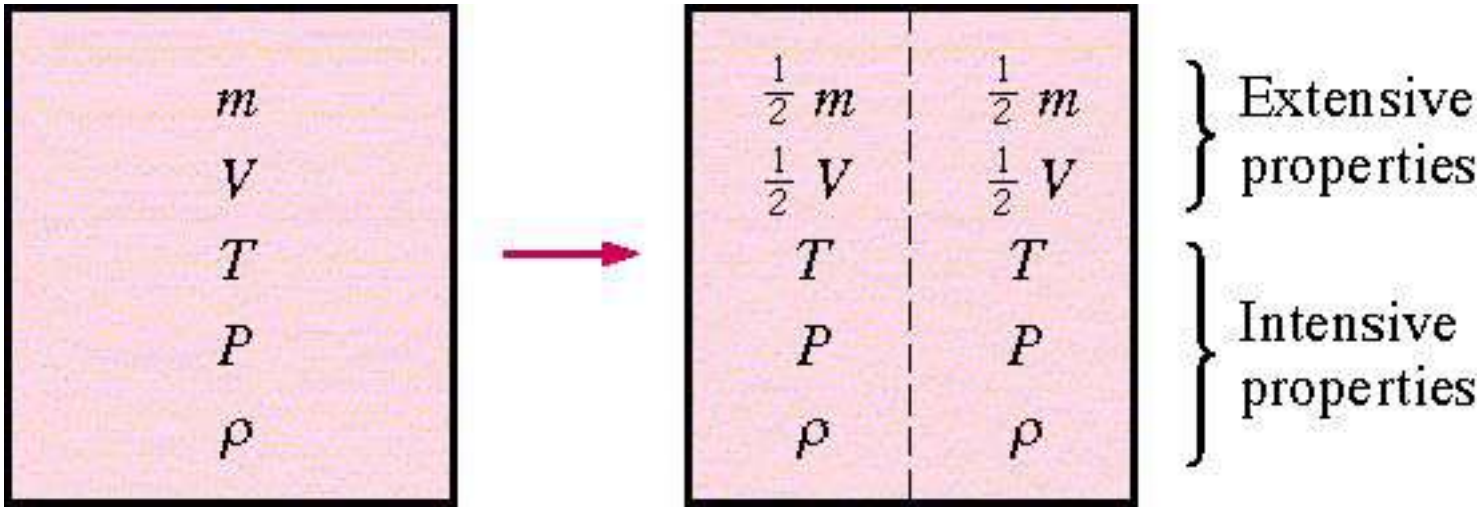
- Every system has certain characteristics like volume, temperature, Pressure, mass, density by which its physical condition may be described. Such characteristics is known as **thermodynamic properties.**

Types of Thermodynamic Properties

- ***Extensive properties*** are the mass-dependent properties of a system. i.e. the properties that will vary proportionally with mass of the system. E.g. volume

- ***Intensive properties*** are the properties that are independent of mass.
  Eg. Temperature, density.

Intensive and Extensive Properties



State of a System

- Definition - A set of properties that completely describe the conditions or characteristics of a system

- **At a given state, all the properties of a system have fixed values**

- State of a system will change when the properties of a system change

Change of State

- Any operation in which one or more of properties of system changes is known as change of state.

Steady state

Steady state

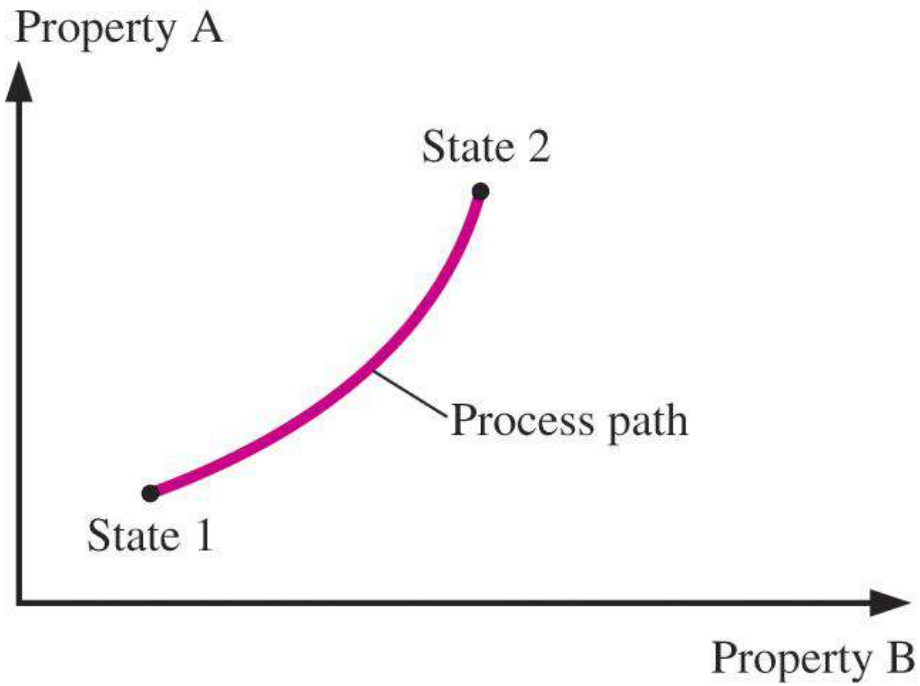
Under the steady state condition, the properties of the system at any location are independent of time.

Thermodynamic Equilibrium

- ***Thermodynamics*** deals with ***Equilibrium States***
- A system is said to be in ***thermodynamic equilibrium*** if it maintains thermal, mechanical, phase, and chemical equilibrium.
- ***Thermal Equilibrium*** => ***Temperature*** is the same throughout the system
- ***Mechanical Equilibrium*** => Mechanical equilibrium means there is no unbalanced force.
- ***Phase Equilibrium*** => ***No phase change*** process in the system
- ***Chemical Equilibrium*** => ***No chemical reactions***

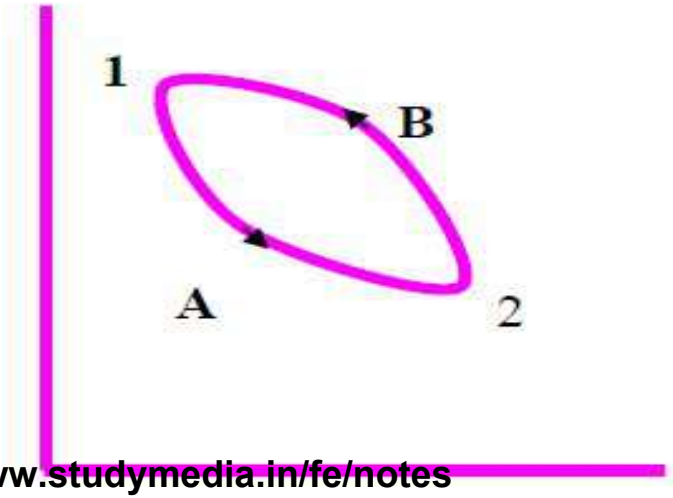
Process, Path and Cycle

- ***Process*** - When the system changes from one equilibrium state to another state, then the change of state is called a process**.**



- ***Path*** - The series of state through which a system passes during a process is called **a *path***

- ***Cycle*** - A process with identical end states is called a ***cycle*****.**

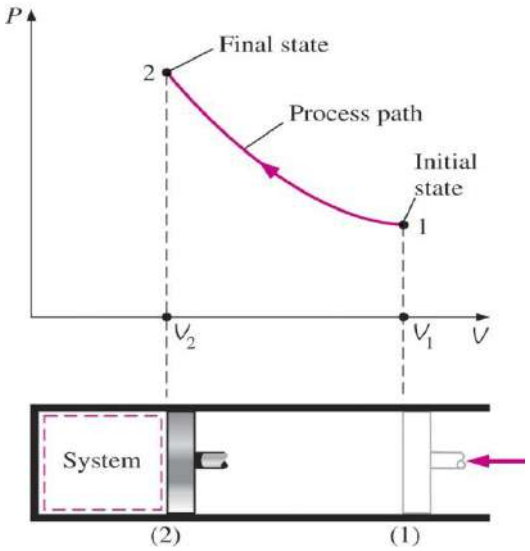


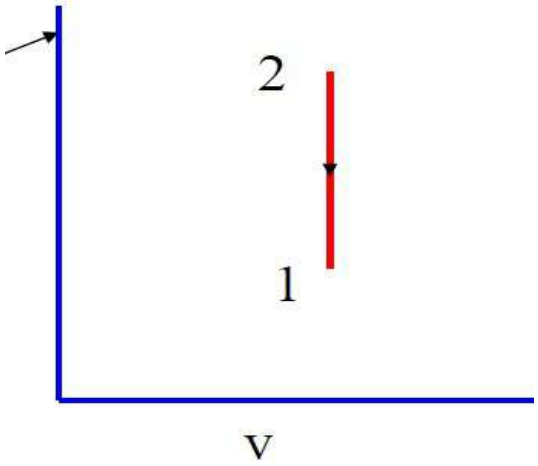
TYPES OF PROCESS

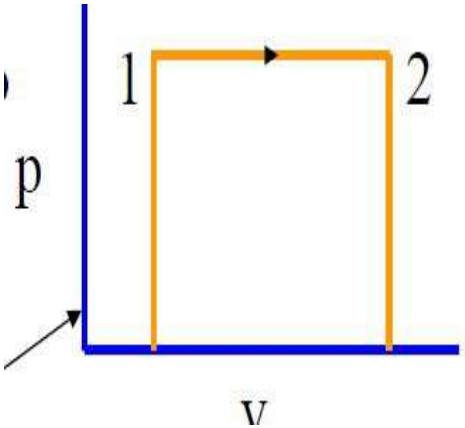
Isothermal process: A process during which the temperature *T* remains constant.

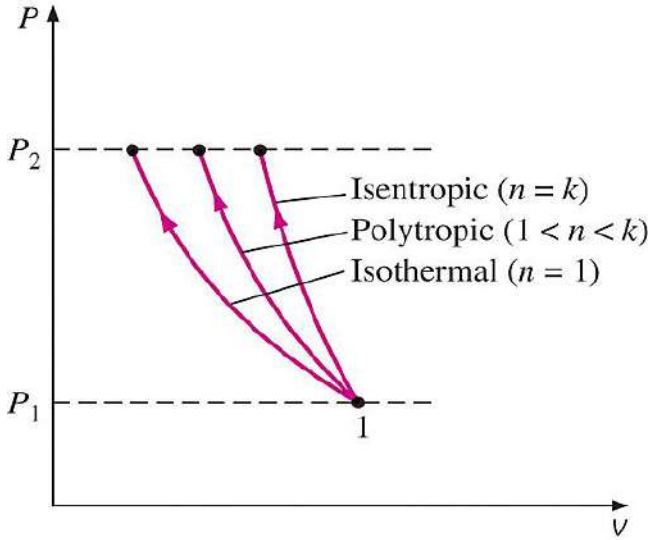
Isobaric process: A process during which the pressure *P* remains constant.

Isochoric (or isometric) process: A process during which the specific volume *v* remains constant.





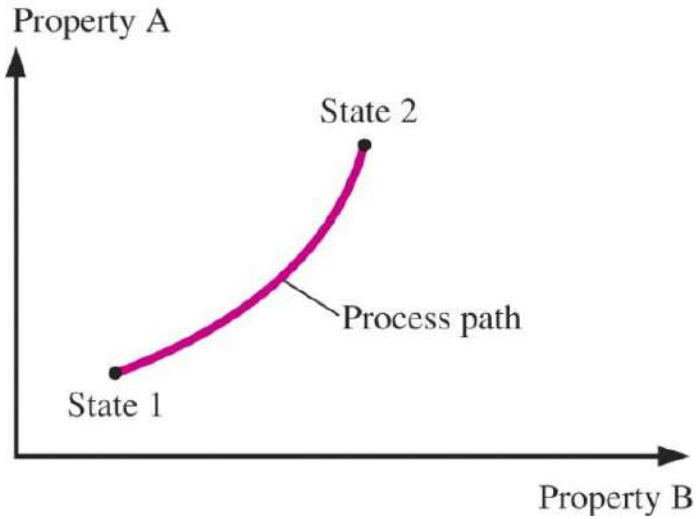




POINT FUNCTION AND PATH FUNCTION

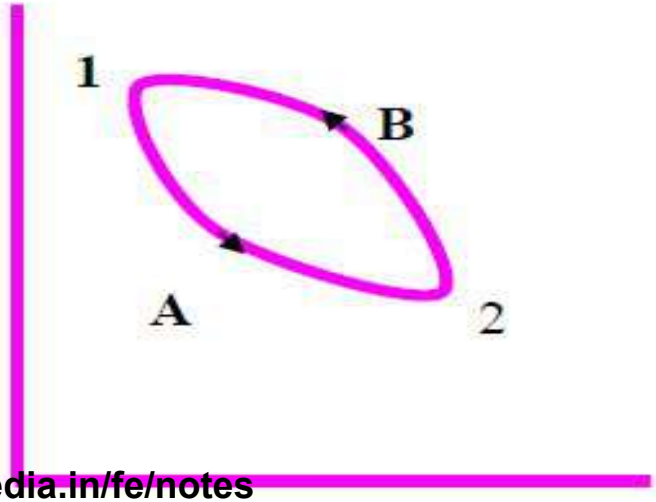
Point function:

When a system undergoes a change from one state to another the properties of the system depends only on end states and not on the path followed between these two states. Therefore ,properties are called state function or **point function.**



Path Function :

A quantity whose value depends on the particular path followed during any process is called as **path function**.



Quasi-Equilibrium Process

- ***Definition*** - A process whereby the system remains infinitesimally close to an equilibrium states at all times

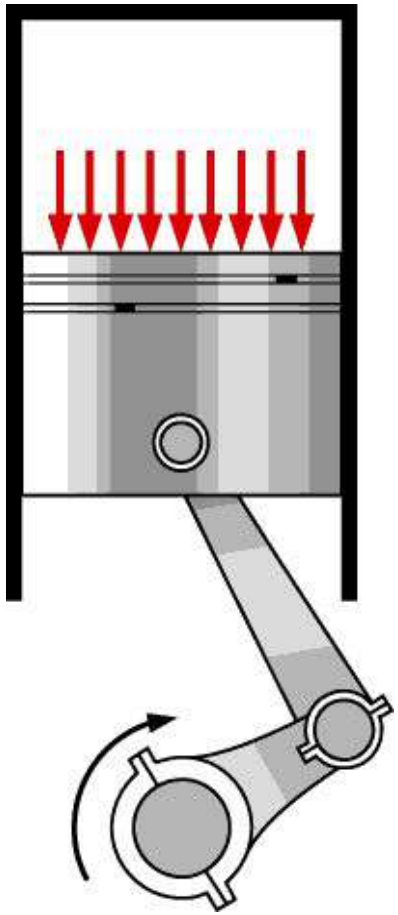
- During a ***quasi-static*** or ***quasi-equilibrium*** process, the system remains practically in equilibrium at all times

- A sufficiently slow process that allows the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts

Quasi-Equilibrium Work Producing Device

Quasi-Equilibrium Process is Idealized Process

Many Real Process Closely Approximate Quasi-Equilibrium Process



Quasi-Equilibrium Process Delivers the Most Work

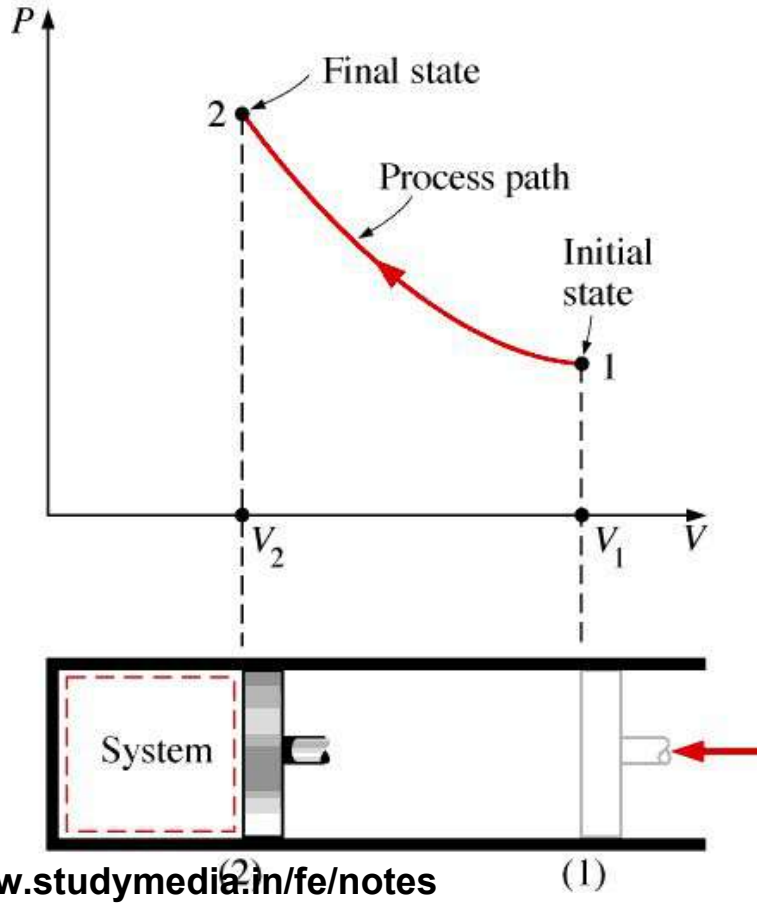
State, Path, Process and Cycle

Compressed Process P-V Diagram

Each Point Along the Path is in Quasi-Equilibrium State

If the Process returns to its initial State then we have a Cycle

If the Outgoing and Returning Paths are Different ~ Net work is Produced (+ve or -ve)



Form of Energy

- The sum of all forms of energy of a system is called ***Total Energy***, which is considered to consist of internal, kinetic, and potential energies.

$$E = U + mV^2/2 + mgz$$

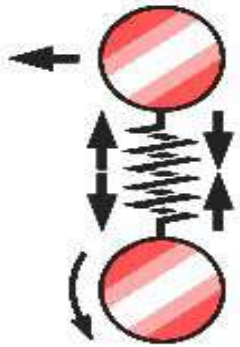
- ***Internal energy*** represents the molecular energy of a system and may exist in sensible, latent, chemical, and nuclear forms. Represented by symbol, ***U***.

- ***Kinetic Energy*** is the energy that a system possesses as a results of its motion relative to some reference frame. $KE = mV^2/2$

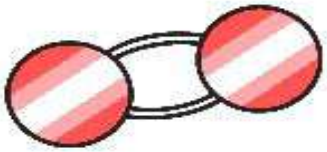
- **Potential Energy** is the energy that a system possesses as a results of its elevation in a gravitational field. $PE = mgz$

System's Internal Energy

System's Internal Energy = Sum of Microscopic Energies



SENSIBLE AND LATENT ENERGY



CHEMICAL ENERGY

NUCLEAR ENERGY

Force - defined as a force when applied to a body having mass of 1kg ,gives acceleration of 1 m/s.

unit – Newton

Work – which is defined as work done when a force of 1 newton is exerted through a distance of 1 m in the direction of force . Unit is joule .

hence 1 joule= 1 Nm

Energy - capacity for doing work ,different types of energy such as mechanical ,chemical electrical**,**

$1kwh=3.6x10^6$ J

Power – Rate of doing work 1joule /sec or 1 Newton /sec

1Nm/s= 1J/s=1watt

Pressure- force applied per unit area . 1 pascal= 1 N/m^2

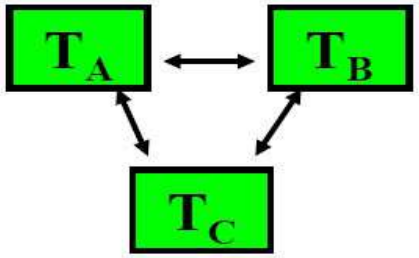
1 bar= 10^5 N/M^2=10^5 Pa

Zeroth Law of Thermodynamics

- *Temperature* is a measure of *'hotness'* or *'coldness'*
- **The *zeroth law of thermodynamics* states that two bodies are in *thermal equilibrium* if both have the *same temperature reading* even if they are not in contact.**
- Basis for validity of Temperature Measurement
- More fundamental than 1st and 2nd Laws of Thermodynamics

Zeroth Law Of Thermodynamics

➢If two systems (say A and B) are in thermal equilibrium with a third system (say C) separately (that is A and C are in thermal equilibrium; B and C are in thermal equilibrium) then they are in thermal equilibrium themselves (that is A and B will be in thermal equilibrium

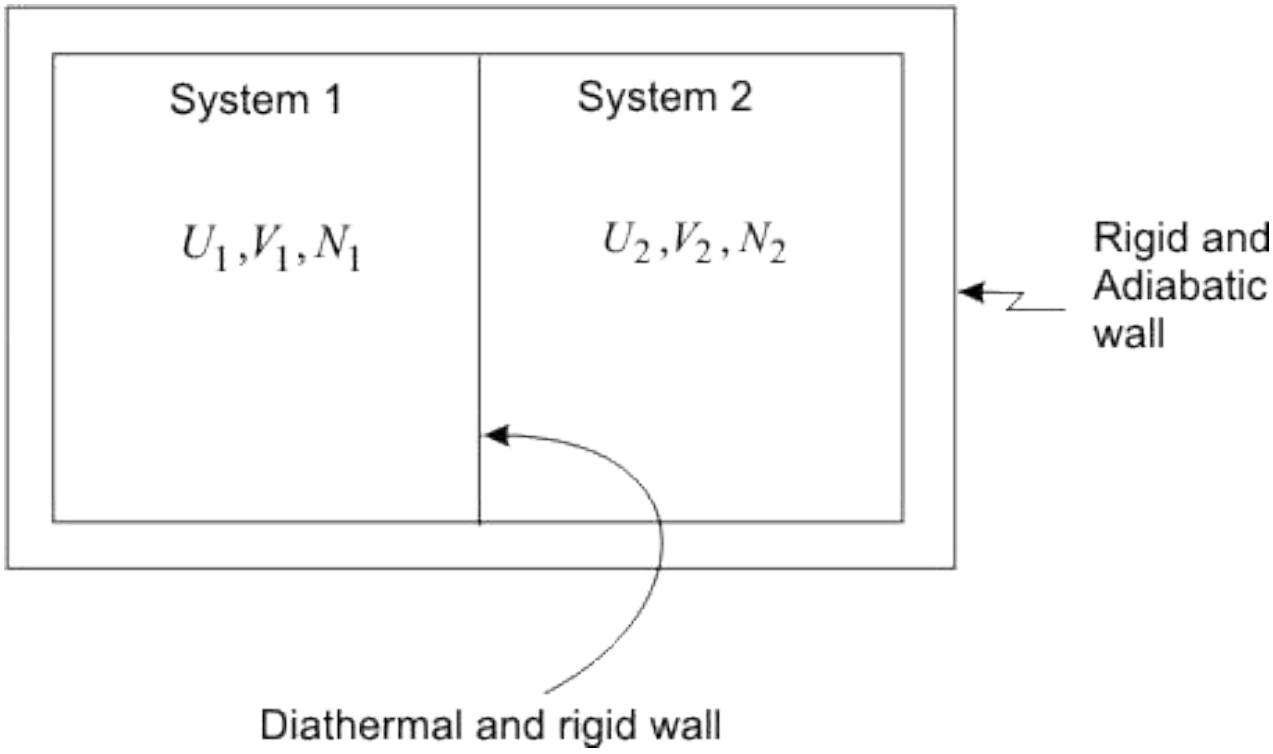


$T_a = t_c$

$T_b = t_c$ A and B will also be in thermal equilibrium $T_A = T_B$

Zeroth Law of Thermodynamics

Statement: If a body 1 is in thermal equilibrium with body 2 and body 3, then the body 2 and body 3 are also in thermal equilibrium with each other



First Law of Thermodynamics

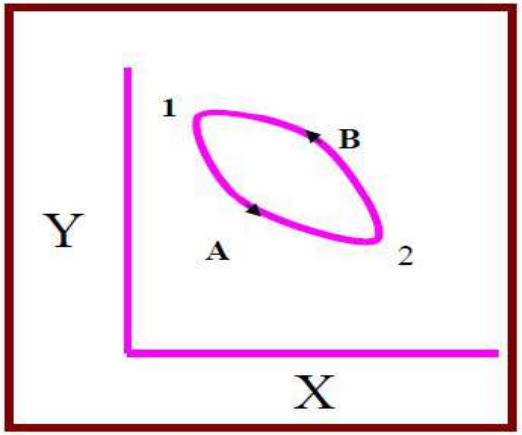
Statement:

- When a closed system executes a complete cycle the sum of heat interactions is equal to the sum of work interactions.

Mathematically

- $\Sigma Q = \Sigma W$

The summations being over the entire cycle



Alternate statement:

When a closed system undergoes a cycle the cyclic integral of heat is equal to the cyclic integral of work.

Mathematically $\oint \delta Q = \oint \delta W$

In other words for a two process cycle

$$Q_{A1\text{-}2} + Q_{B2\text{-}1} = W_{A1\text{-}2} + W_{B\,2\text{-}1}$$

First Law of Thermodynamics :- Joules Experiment

A series of Experiments carried out by Joule between 1843 and 1848 from the basis for the **First Law of Thermodynamics**

The following are the observations during the Paddle Wheel experiment shown in Fig

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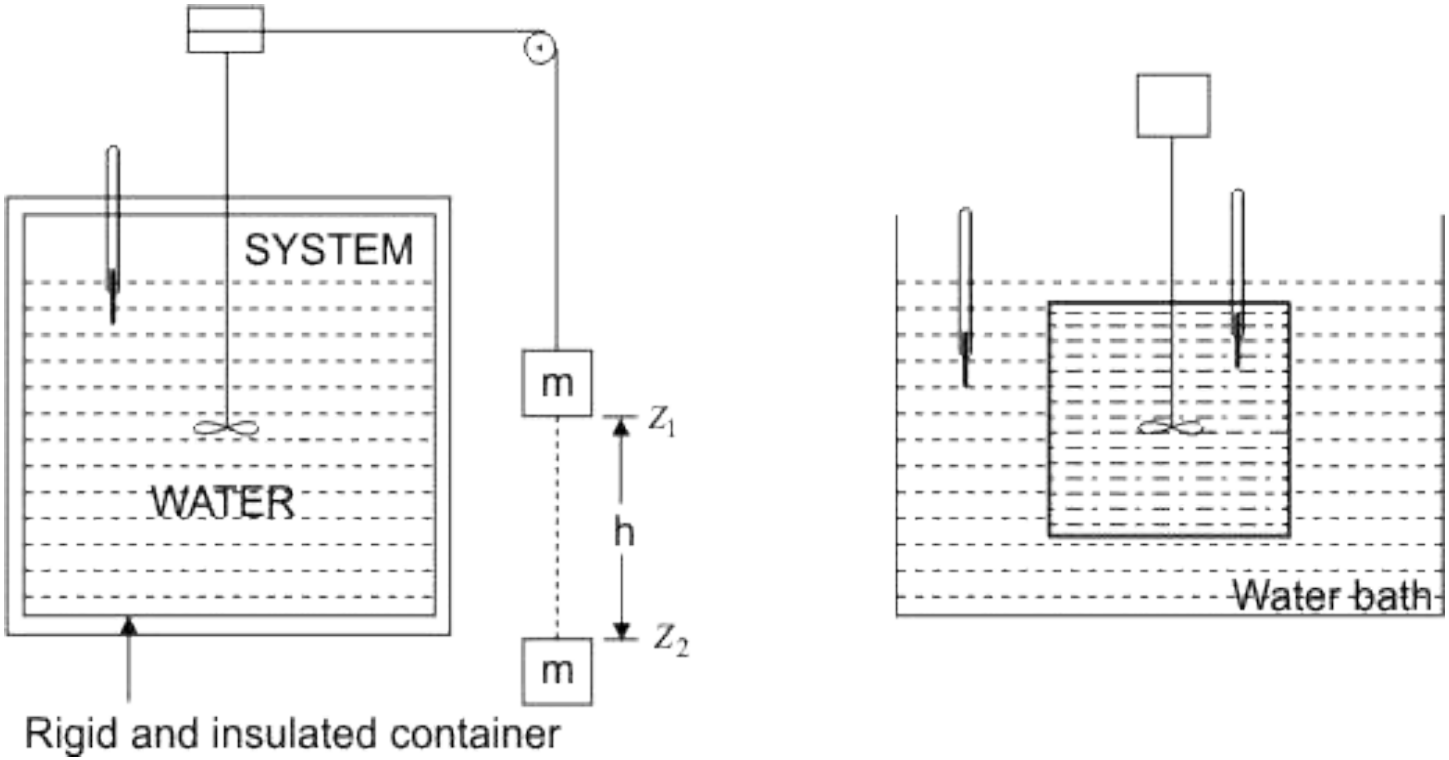
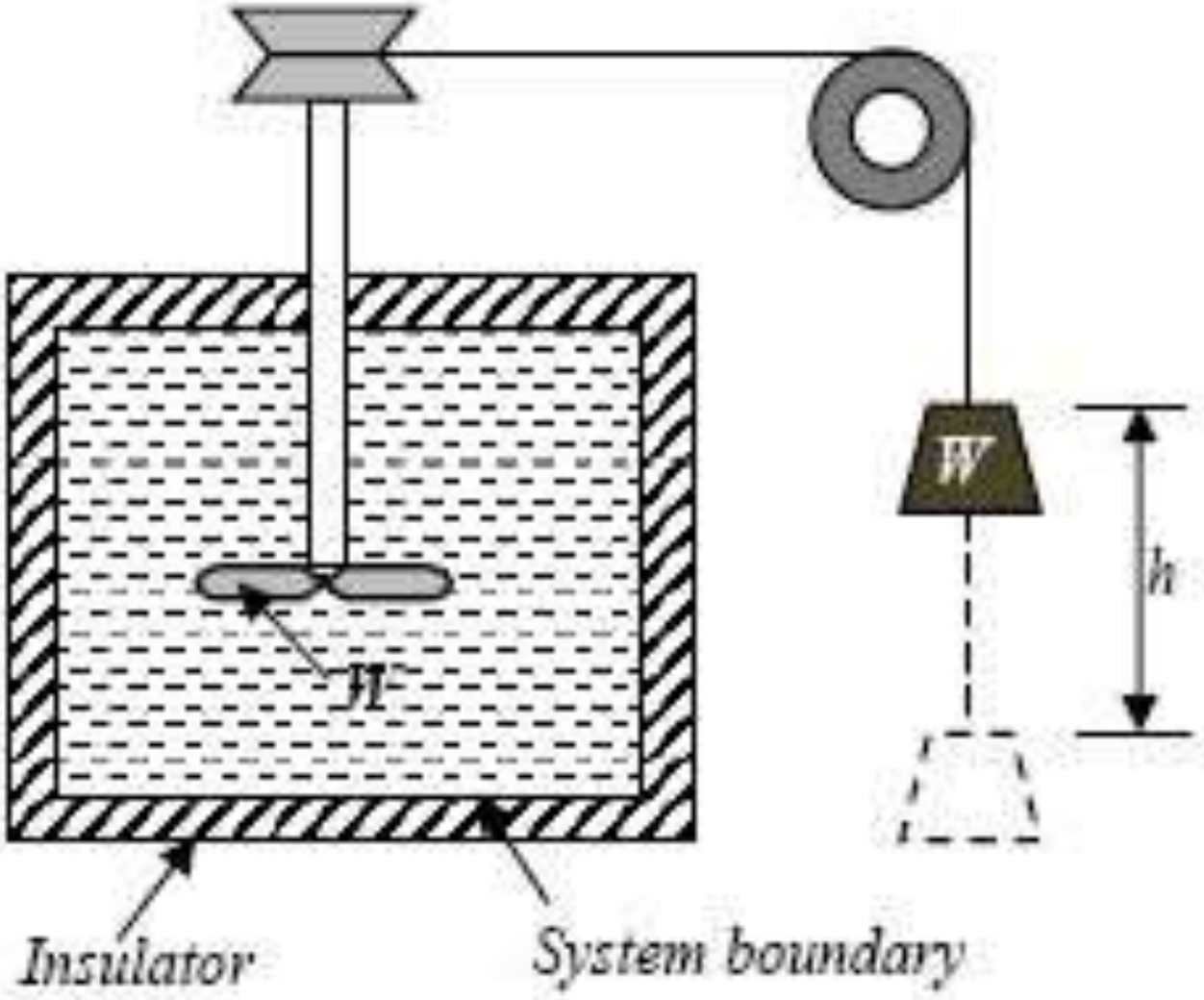
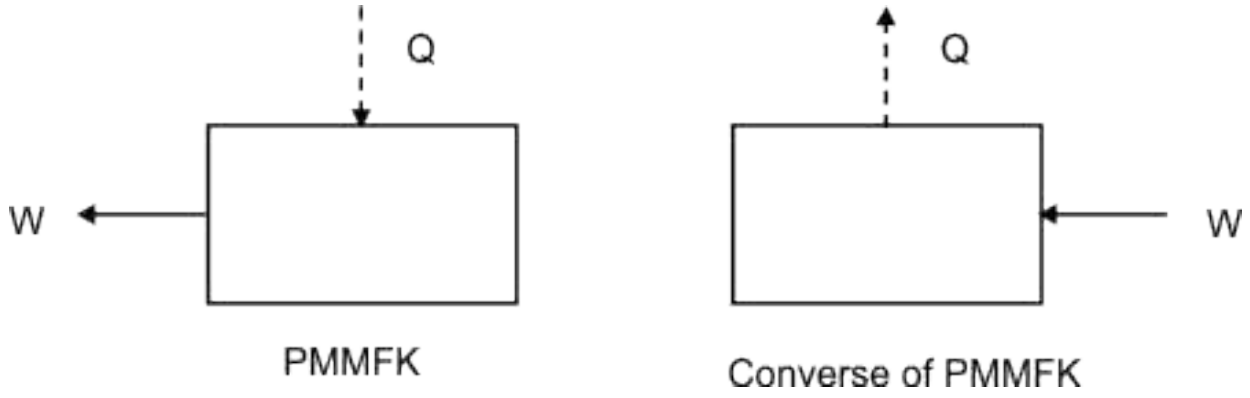


Joule's Experiment



A Perpetual Motion Machine of First Kind



An imaginary device which would produce work continuously without absorbing any energy from its surroundings is called a Perpetual Motion Machine of the First kind, (PMMFK). A PMMFK is a device which violates the first law of thermodynamics. It is impossible to devise a PMMFK .

The converse of the above statement is also true, i.e., there can be no machine which would continuously consume work without some other form of energy appearing simultaneously.

Limitation of First Law of Thermodynamics

- No limit to amount of total energy of a system which can be caused to flow out as work

- Does not specifies condition under which conversion of heat into work is possible neither the direction in which heat transfer can take place.

Second Law Of Thermodynamics

Kelvin Plancks Statement

Statement 1: It is impossible to construct a device which operating in a cycle will produce no effect other than raising of a weight and exchange of heat with a single reservoir.

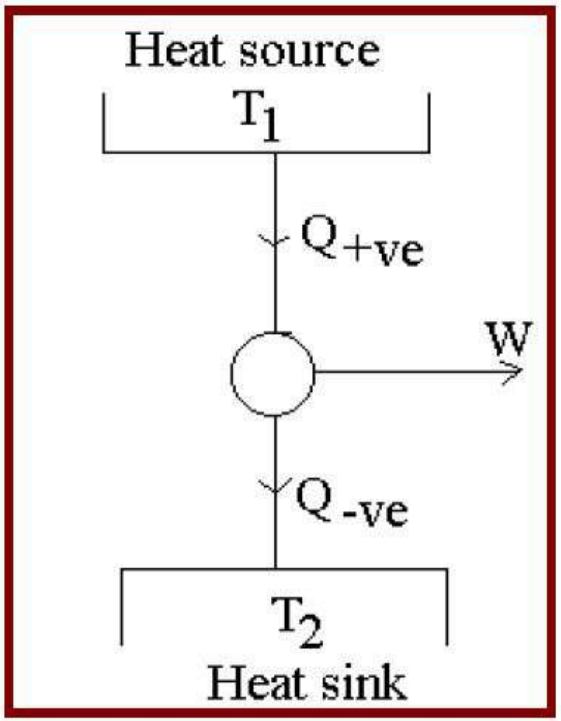
Clausius Statement of II Law of Thermodynamics

It is impossible to construct a device which operates in a cycle and produces no effect other than the transfer of heat from a cooler body to a hotter body.

Heat Engine

- A heat engine is a device which converts the energy it receives at heat, into work.
- It is a cyclically operating device.
- **It receives energy as heat form a high temperature body, converts part of it into work and rejects the rest to a low temperature body.**

A thermal power plant is an example of a heat engine



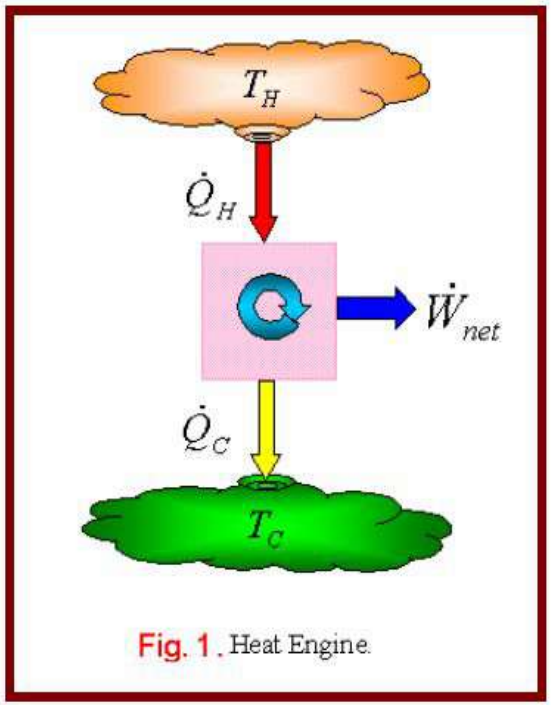
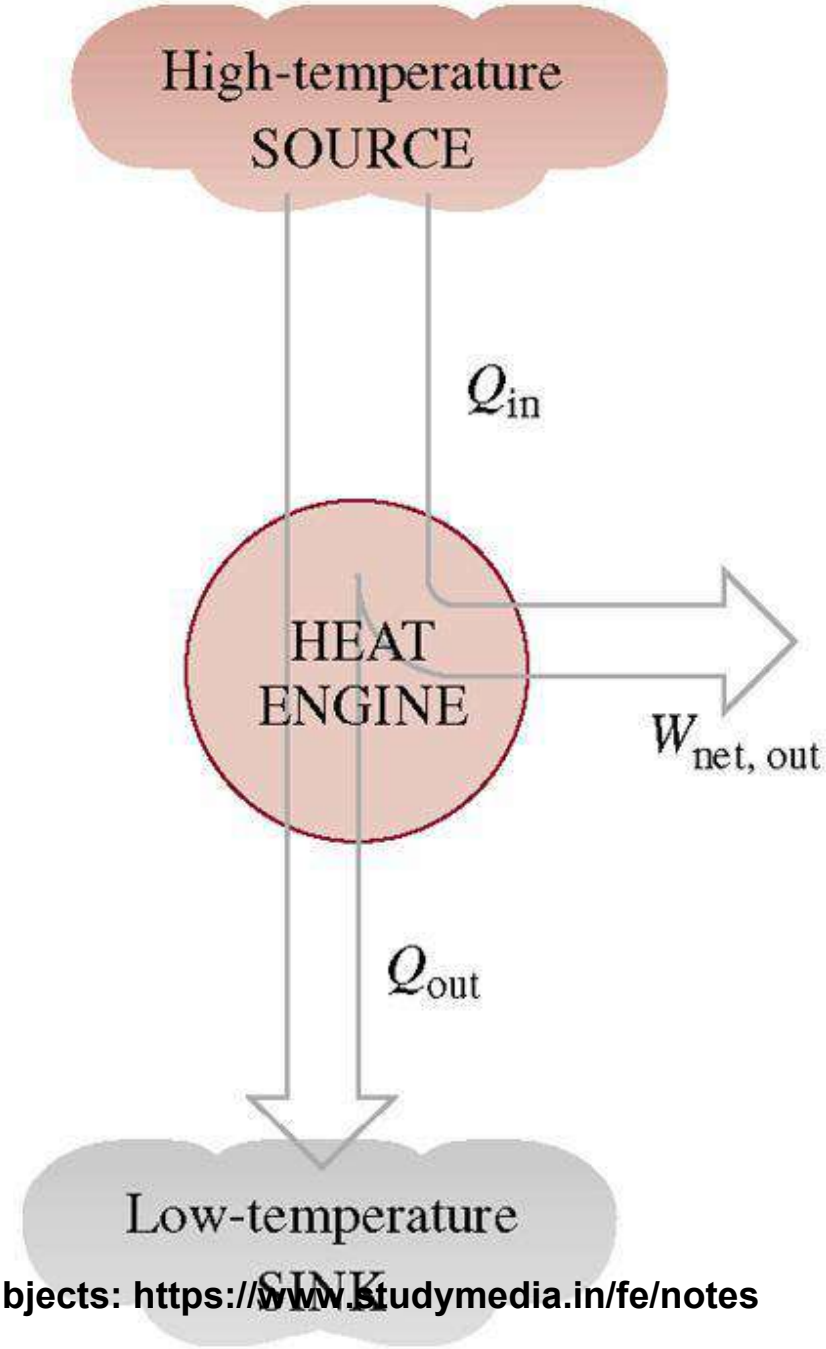
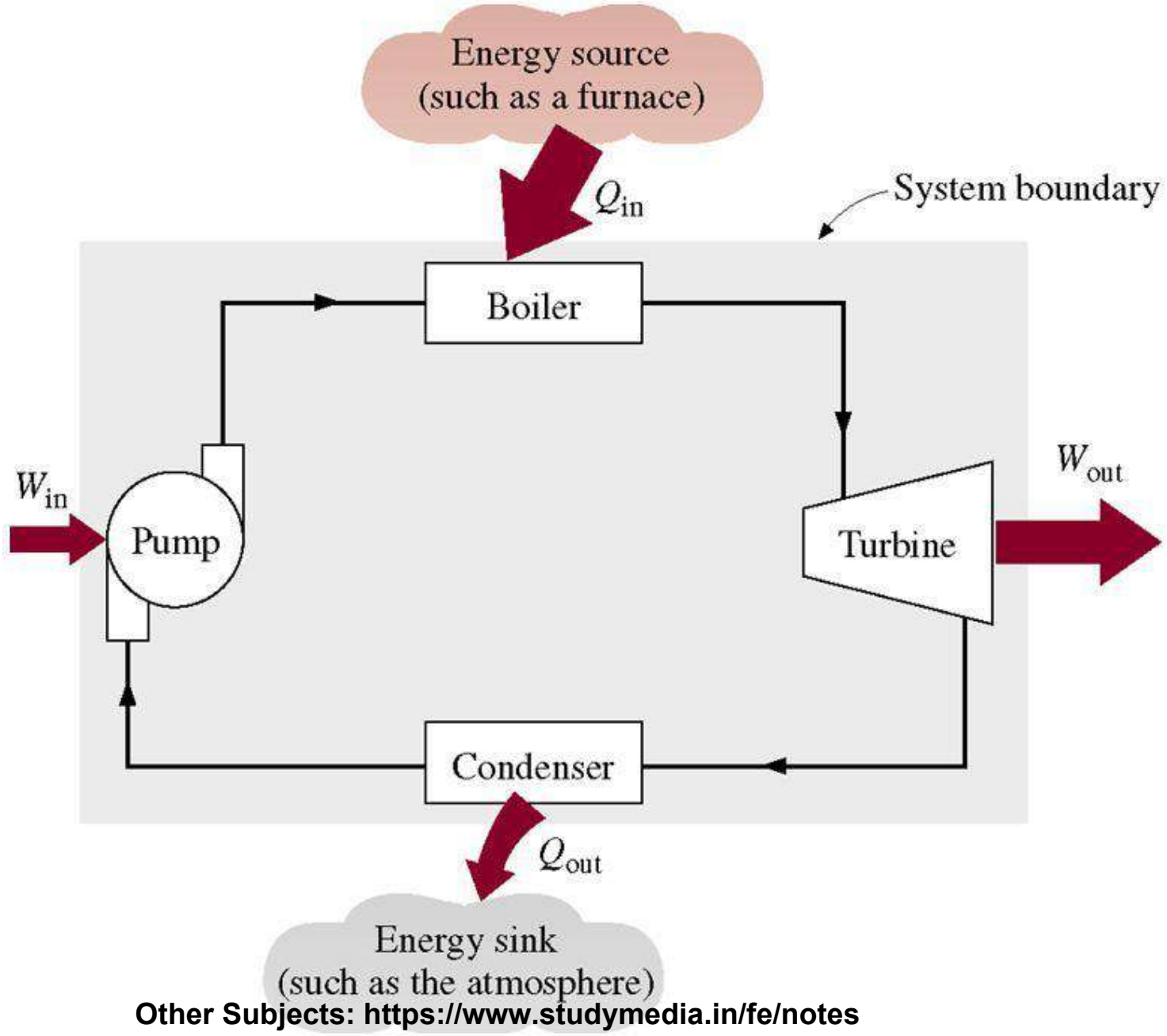


Fig. 1 . Heat Engine.





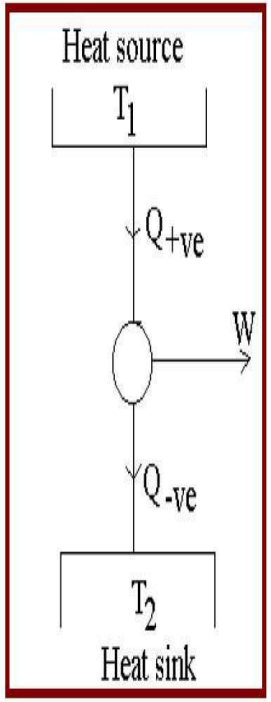
Work done by the system

Energy absorbed as heat by the system

Energy rejected as heat by the system

According to first law of thermodynamics, the heat and work interaction are related by the equation

Finally, the thermal efficiency



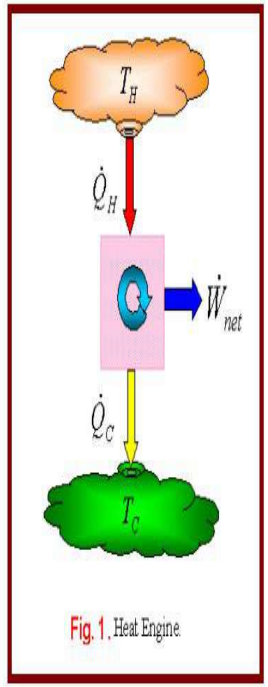
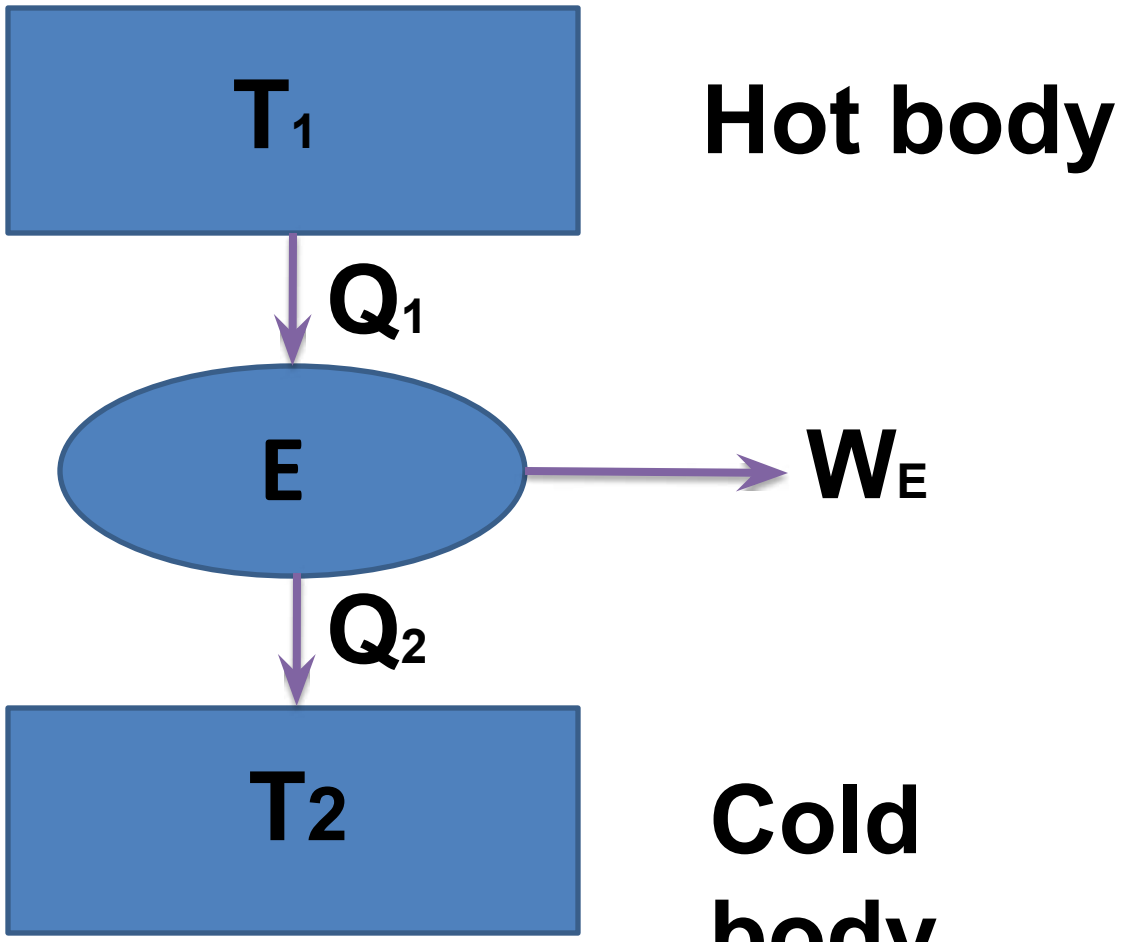


Fig. 1. Heat Engine

Heat engine



$T_1 > T_2$

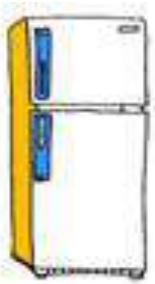
Refrigerator

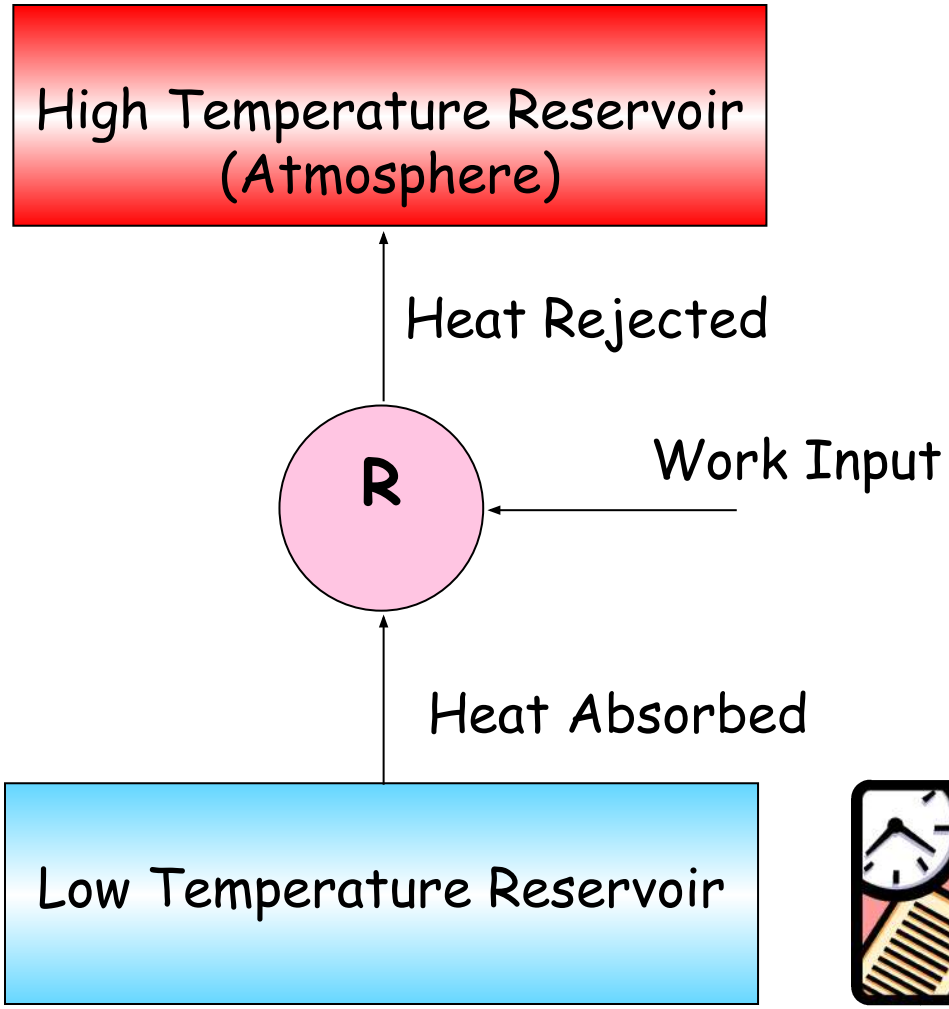
- A refrigerator is a cyclically operating device which absorbs energy as heat from a low temperature body and rejects energy as heat to a high temperature body when work is performed on the device.

- **The objective of this device is to refrigerate a body at low temperature.**

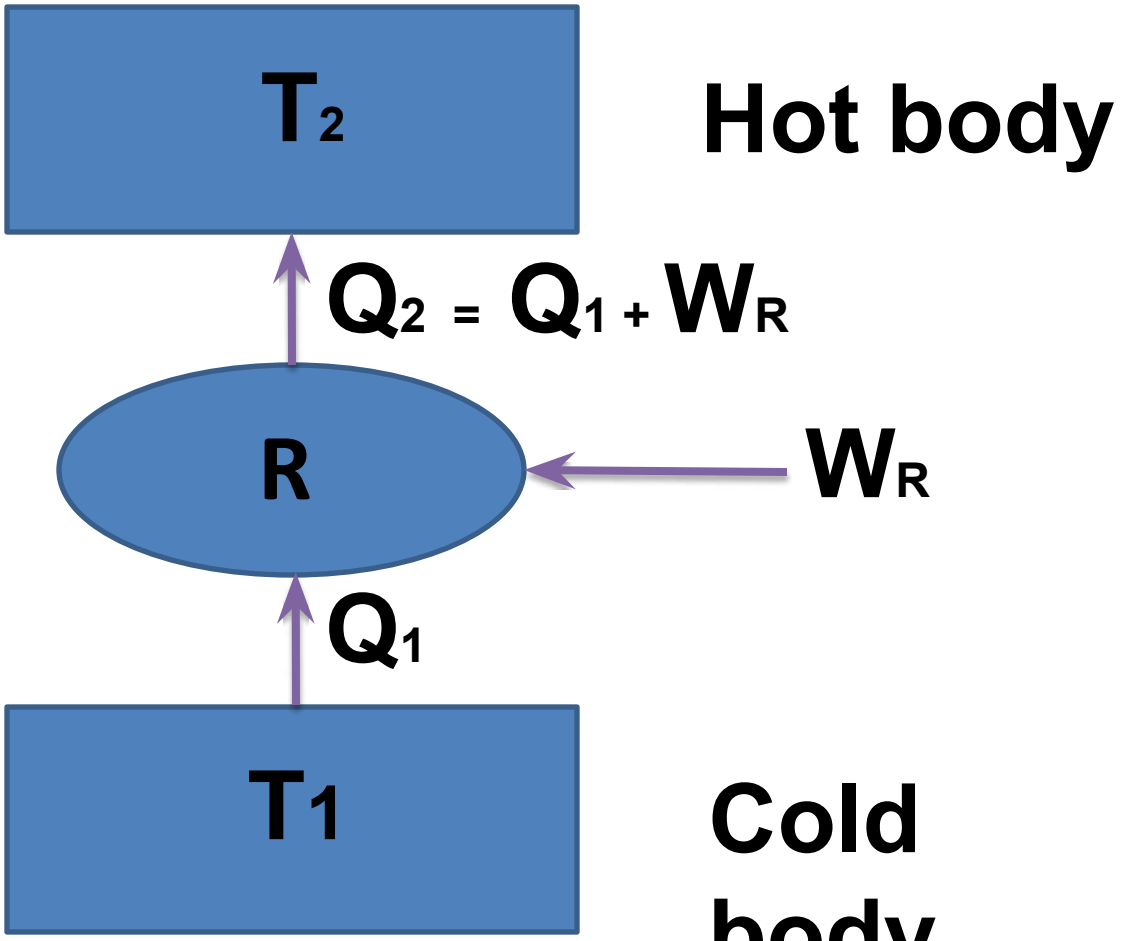
- Usually it uses atmosphere as the high temperature reservoir.

- The efficiency of Refrigerator & Heat Pump is expressed in terms of **Coefficient of Performance (COP)**





Refrigerator



COP = Desired effect

Energy Input

COP = Q1/Wr

COP = Q1/Q2-Q1

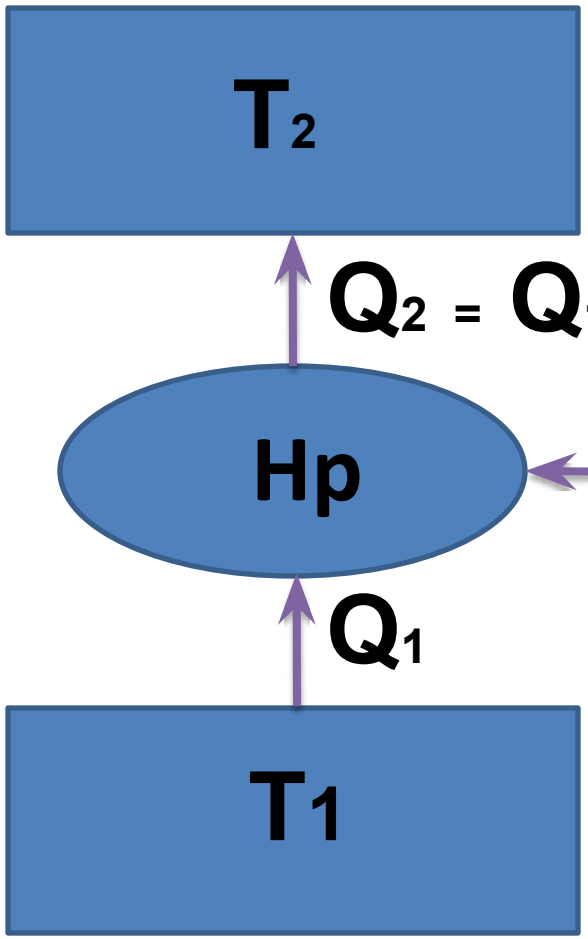
Heat Pump

- Heat Pump is cyclically operating device which absorbs energy form a low temperature reservoir and reject energy as heat to a high temperature reservoir when work is performed on the device.

- **Its objective is to reject energy as heat to a high temperature body (space heating in winter).**

- The atmosphere acts as the low temperature reservoir.

Heat pump



COP = Desired effect

Energy Input

COP = Q2/Wp

COP = Q2/Q2-Q1

Difference between Heat Engine and Heat Pump

Heat Engine	Heat Pump
It is a work developing device	It is a work absorbing device
It obeys Kelvin Plank's statement of second law of thermodynamics.	It obeys Clausius statement of second law of thermodynamics.
In heat engine, heat is supplied from a heat source and mechanical work is produced with rejection of some quantity of heat to heat sink	In heat pump, heat is pumped from heat sink and it is supplied to a hot body on consuming external work supplied
Its performance is measured in terms of "Efficiency" $\eta = W / Q1$	Its performance is measured in terms of "Coefficient of Performance" $COP = Q2 / W$
Efficiency is always less than 100%	COP is always greater than 1

Difference between Heat Engine and Refrigerator

Heat Engine	Refrigerator
It is a work developing device	It is a work absorbing device
It obeys Kelvin Plank's statement of second law of thermodynamics.	It obeys Clausius statement of second law of thermodynamics.
In heat engine, heat is supplied from a heat source and mechanical work is produced with rejection of some quantity of heat to heat sink	In refrigerator, heat is pumped from heat sink and it is supplied to a hot body on consuming external work supplied
Its performance is measured in terms of "Efficiency" $\eta = W / Q1$	Its performance is measured in terms of "Coefficient of Performance" $COP = Q1 / W$
$\eta = (T1 - T2) / T1$	$COP = T2 / (T1 - T2)$

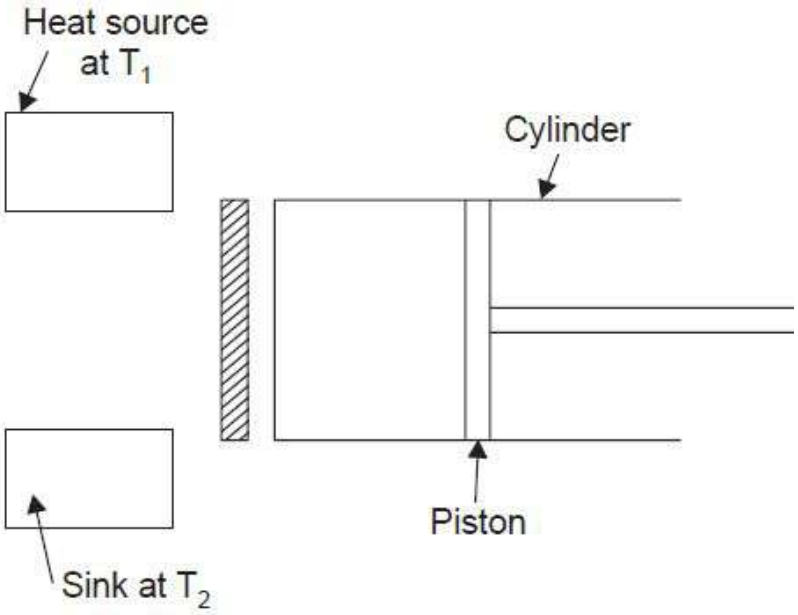
ENTHALPY:- (h)

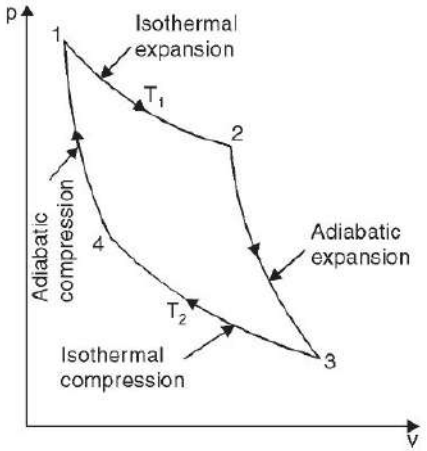
- The total heat content of the system
- The sum of internal Energy (U) & pressure volume Product (PV) is known as **Enthalpy.**
- **h = U + PV**

CARNOT CYCLE

The cycle was first suggested by a French engineer Sadi Carnot in 1824 which works on reversible cycle and is known as *Carnot cycle.*

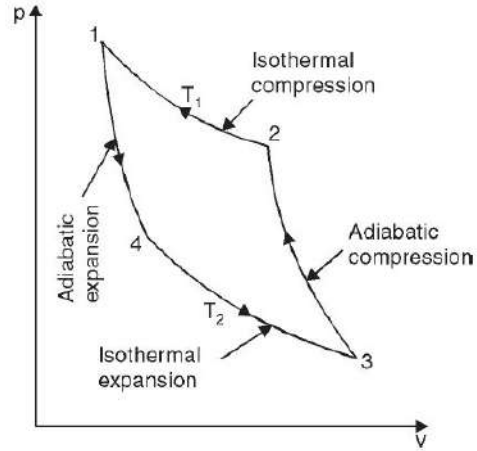
Carnot cycle which is performed in an engine cylinder the head of which is supposed alternatively to be perfect conductor or a perfect insulator of a heat.





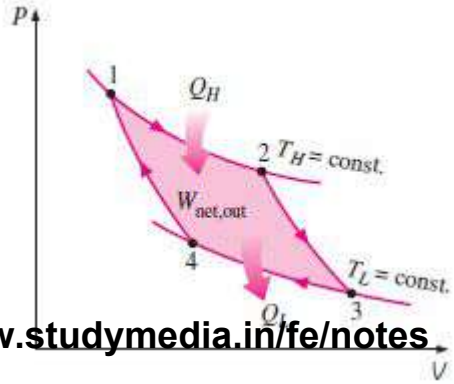
(b)

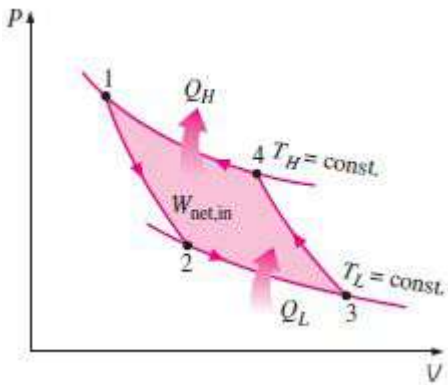
Carnot engine cycle



(c)

Carnot heat pump cycle





The ***assumptions*** *made for describing the working of the Carnot engine are as follows :*

(*i) The piston moving in a cylinder does not develop any friction during motion.*
(*ii) The walls of piston and cylinder are considered as perfect insulators of heat.*
(*iii) The cylinder head is so arranged that it can be a perfect heat conductor or perfect heat* insulator.
(*iv) The transfer of heat does not affect the temperature of source or sink.*
(*v) Working medium is a perfect gas and has constant specific heat.*
(*vi) Compression and expansion are reversible.*

Stage 1. (Process 1-2). Hot energy source is applied. Heat *Q1 is taken in whilst the fluid* expands isothermally and reversibly at constant high temperature *T1.*

Stage 2. (Process 2-3). The cylinder becomes a perfect insulator so that no heat flow takes place. The fluid expands adiabatically and reversibly whilst temperature falls from *T1 to T2.*

Stage 3. (Process 3-4). Cold energy source is applied. Heat *Q2 flows from the fluid whilst* it is compressed isothermally and reversibly at constant lower temperature *T2.*

Stage 4. (Process 4-1). Cylinder head becomes a perfect insulator so that no heat flow occurs. The compression is continued adiabatically and reversibly during which temperature is raised from *T2 to T1.*

The work delivered from the system during the cycle is represented by the enclosed area of the cycle. For a closed cycle, according to first law of the thermodynamics the work obtained is equal to the difference between the heat supplied by the source (*Q1) and the heat* rejected to the sink (*Q2).*

$$\therefore \quad W = Q_1 - Q_2$$

$$\text{Also, thermal efficiency, } \eta_{th} = \frac{\text{Work done}}{\text{Heat supplied by the source}} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} \left(= 1 - \frac{T_2}{T_1} \right)$$

$$\left[\because \quad Q_1 = m\, c_p\, T_1, \quad Q_2 = m\, c_p\, T_2, \quad \text{where, } m = \text{mass of fluid.} \right]$$

The Carnot cycle *cannot be performed in practice because of the following* ***reasons :***

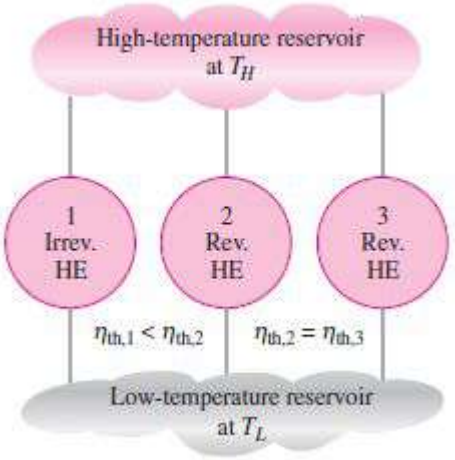
1. It is imposible to perform a frictionless process.

2. It is impossible to transfer the heat without temperature potential.

3. Isothermal process can be achieved only if the piston moves very slowly to allow heat transfer so that the temperature remains contant. Adiabatic process can be achieved only if the piston moves as fast as possible so that the heat transfer is negligible due to very short time available.

CARNOT'S THEOREM

"It states that of all engines operating between a given constant temperature source and a given constant temperature sink, none has a higher efficiency than a reversible engine".



The efficiency of an irreversible heat engine is always less than the efficiency of a reversible one operating between the same two reservoirs.

The efficiencies of all reversible heat engines operating between the same two reservoirs are the same.

NUMERICALS BASED ON HE,HP & REFRIGERATOR

1) Heat at the rate of 1700 kJ/min is supplied to the Heat engine and gives output of 9 kW. Determine thermal efficiency and the rate of heat rejection.(31.76%, 19.33 kW)

2) A heat engine operates between a source temperature of 800C and a sink temperature of 30C. What is the least rate of heat rejection per kW net output of an engine. (0.393 kW)

3) A heat engine operates between a source and sink temperature of 235C and 30C. If heat engine receives 35 kW from the heat source, find (i) The net work done by the heat engine, (ii) The heat rejected to the sink by the engine, and (iii) Efficiency of engine Draw sketch of system. (14.12 kW, 20.87 kW, 40.35%)

4) A heat pump is used to maintained the house at 25C. The house is losing the heat at the rate of 60000 kJ/hr to the surrounding, while the heat generated in the house by various appliances is 4000 kJ/hr. If COP of heat pump is 1.5, find the power required to drive the heat pump. (10.37 kW)

5) A heat pump is used to maintain the house at 24C. The house is losing the heat at the rate of 1800 kJ/min to the surrounding. The heat pump is driven by an electric motor of power 12 kW. Find: (i) The amount of heat absorbed from surrounding and (ii) COP of the heat pump. Draw the sketch of the system.

(18 kW, 2.5)

6) A fish freezing plant is to be maintained at -10C. If the power required to drive the plant is 30 kW and COP of refrigeration system is 3, find:
(i) Heat absorbed from the freezing plant and
(ii) Heat rejected to surrounding
Draw sketch of the system. (90 kW, 120 kW)

7) A household refrigerator with COP of 1.8 removes heat from the refrigerated space at the rate of 90 kJ/min. Determine,

(i) The amount of heat rejected to kitchen,

(ii) Electrical power consumed by refrigerator.

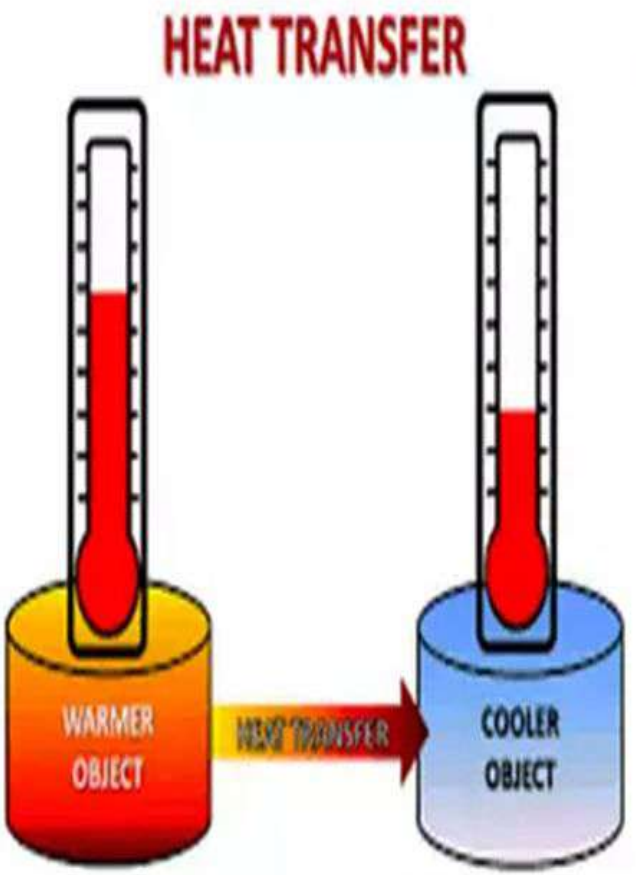
(140 kJ/min, 0.833 kW)

INTRODUCTION TO HEAT TRANSFER

What is Heat transfer ?

- ***Heat transfer tells us:***
- *How (with what modes) dQ is transferred*
- *At what rate dQ is transferred*
- *Temperature distribution inside the body*

- *Heat transfer is classified into various mechanisms, such as thermal conduction , thermal convection , thermal radiation and transfer of energy by phase changes.*

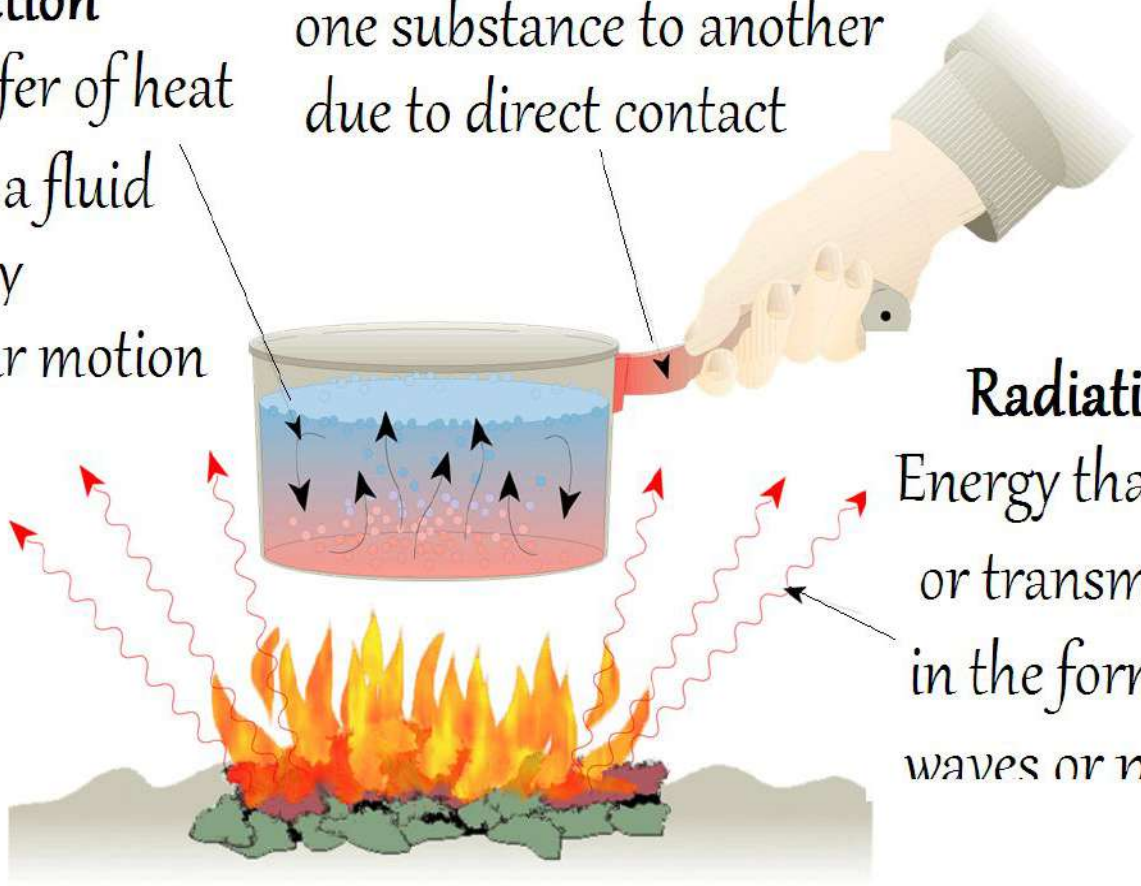


Conduction

The transfer of heat from one substance to another due to direct contact

Convection

The tranfer of heat trought a fluid caused by molecular motion

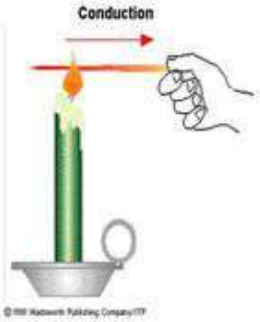


Radiation

Energy that is radiated or transmitted in the form of rays or waves or particles

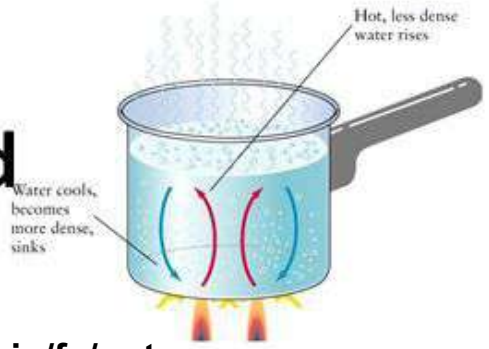
3 Modes of Heat Transfer:

1. Conduction: heat transfer through direct contact



2. Radioactive exchange: heat transfer via electromagnetic waves

3. **Convection: heat transport by a moving fluid (gas or liquid).**



Difference between Thermodynamics and Heat Transfer

Thermodynamics	Heat Transfer
It is the branch of science which deals with energy transfer and its effect on the system.	It deals with the rate of Heat Transfer
Energy transfer in thermodynamics is based on various laws such as: Zeroth law, 1st law, 2nd law and 3rd law of thermodynamics.	Heat transfer between system and surrounding is based on three modes of heat transfer such as: Conduction, Convection and Radiation.
Thermodynamics gives no indication about how long the process takes	Heat Transfer determines how fast heat can be transferred to or from a system and thus the times of cooling or heating
Thermodynamics give information about conversion of heat into work.	Heat transfer provides information about the rate of heat transfer.
It provides state point properties of the system	It provides temperature distribution inside the material.
Application of thermodynamics: Heat engine, Heat pump, refrigerator	Application of Heat transfer: Heat exchangers, condenser, evaporator

Application of Heat Transfer

1) Automobile
2) Milk chillers and dairy industries
3) Ice plant
4) IC engines
5) Steam and Gas Turbines power plants
6) Food Industries
7) Refrigeration and air conditioning
8) Medicine preservation
9) Solar power plant
10) Electronic cooling
11) Electric vehicles

NUMERICALS BASED ON CONDUCTION

1) The inner surface of a brick-wall is at 42C and the outer surface is at 22C. Calculate the rate of heat transfer, if the wall is 3m*6m in cross section. It is 250 mm thick and thermal conductivity of the wall is 0.55 W/mK. (792 W)

2) Determine rate of heat flux through the boiler wall made of 3cm thick steel and covered with an insulating material of 0.5 cm thick. Temperature of wall inside boiler is 300C and temperature of outer surface is 50C.
   Assume: K for steel = 60 W/mK
   K for insulation = 0.12 W/mK (5928.85 W/m^2)

NUMERICALS BASED ON CONVECTION

1) A hot plate of 1m*1.5m is maintained at 300C. Air at 25C blows over the plate. If the convective heat transfer coefficient is 20 W/m2C, calculate rate of heat transfer. (8250W)

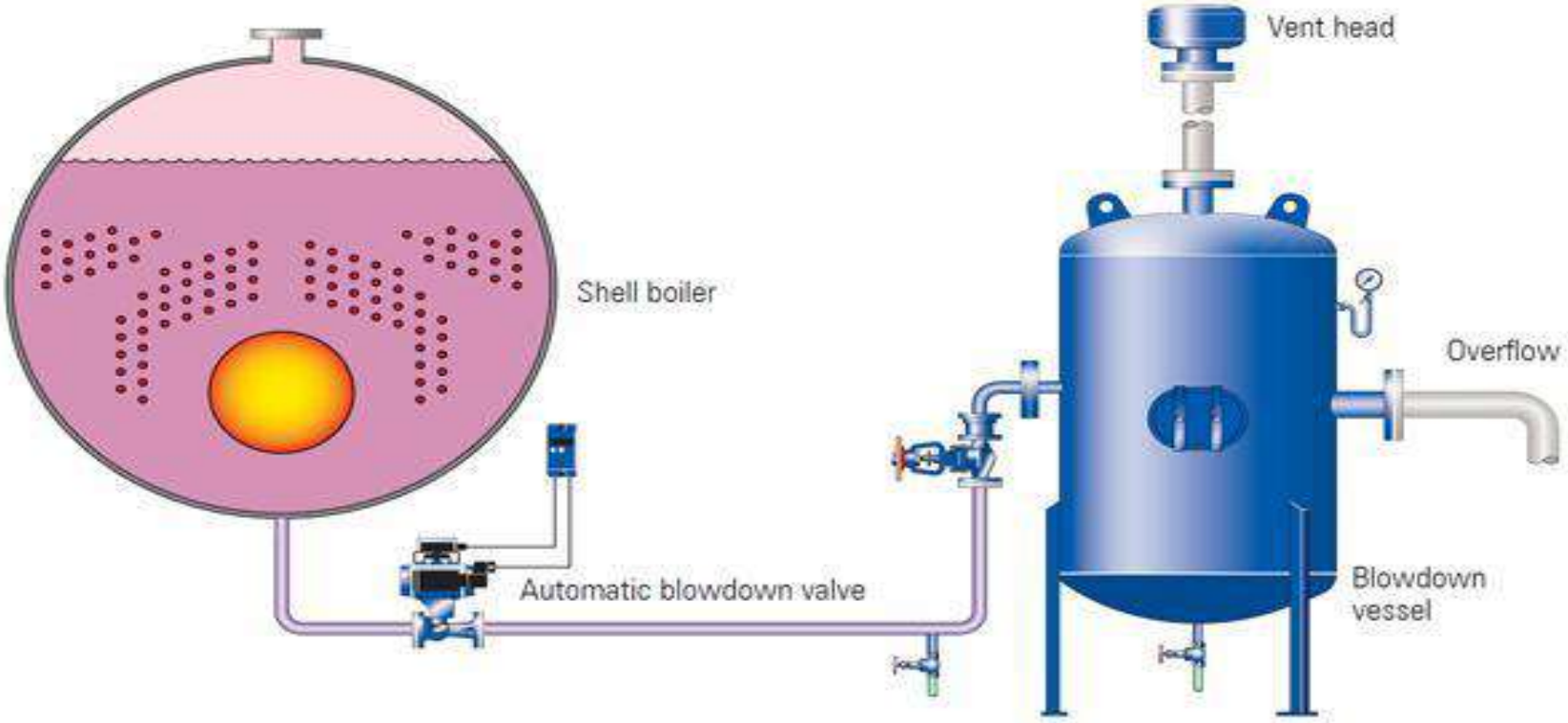
2) A wire 1.5 mm in diameter and 150mm long is submerged in water at atmospheric pressure. An electric current is passed through the wire and is increased until the water boils at 100C. Under this condition, if convective heat transfer coefficient is 4500 W/m2C, find how much electric power must be supplied to the wire to maintain the wire surface at 120C? (63.61W)

NUMERICALS BASED ON RADIATION

1) The effective temperature of a body having an area of 0.12 m^2 is 527°C. Calculate the total rate of energy emission. (2786.9 W)

2) Calculate the total emissive power for an industrial furnace emitting radiation at 2500°C. ($3.352*10^6$ W/m^2)

BOILERS



BOILER

- A boiler is defined as a closed vessel in which steam is produced from water by combustion of fuel.

- Usually made of steel in which chemical energy of fuel is converted by combustion into heat

- Heat energy of products of combustion is transferred to water so as to produce steam.

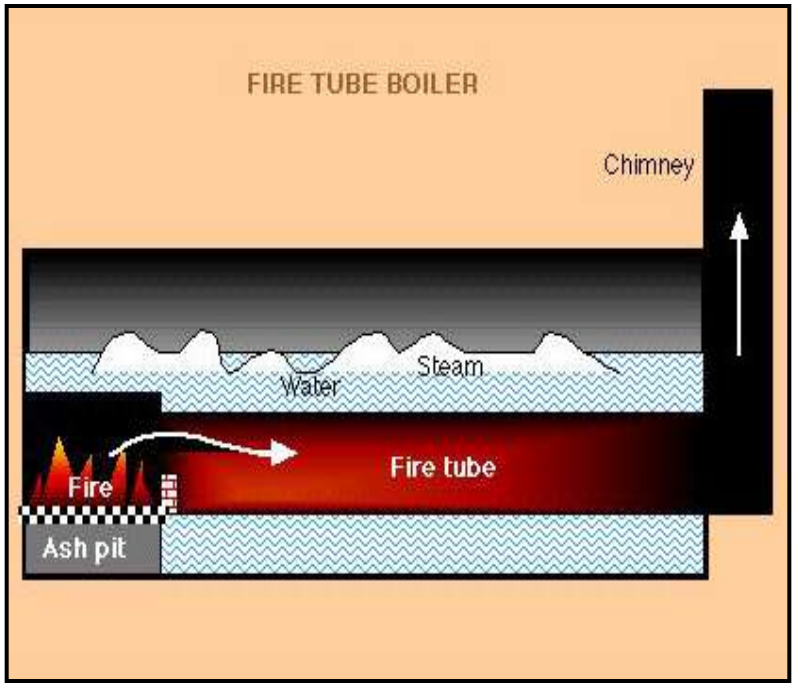
TYPES OF BOILERS

1. FIRE TUBE BOILERS
2. WATER TUBE BOILERS
3. INTERNALLY FIRED BOILERS
4. EXTERNALLY FIRED BOILERS
5. VERTICAL BOILERS
6. HORIZONTAL BOILERS
7. NATURAL CIRCULATION
8. FORCED CIRCULATION
9. LOW PRESSURE BOILER
10. HIGH PRESSURE BOILER

Type of Boilers

Thermal Equipment/ Boilers

1. Fire Tube Boiler

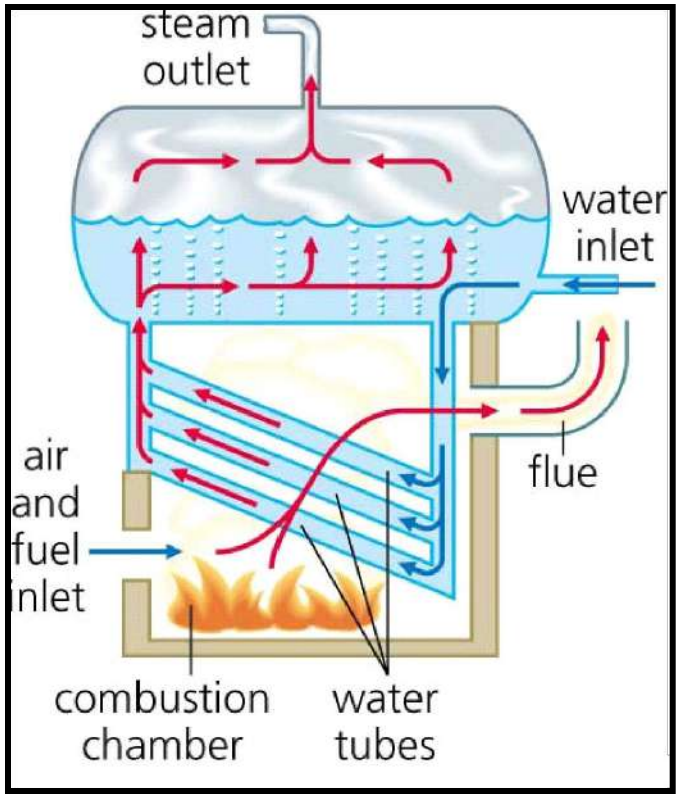


- Relatively small steam capacities (12,000 kg/hour)
- Low to medium steam pressures (18 kg/cm2)
- Operates with oil, gas or solid fuels

(Light Rail Transit Association)

Type of Boilers

2. Water Tube Boiler



(Your Dictionary.com)

- **Used for high steam demand and pressure requirements**
- **Capacity range of 4,500 – 120,000 kg/hour**
- **Combustion efficiency enhanced by induced draft provisions**
- **Lower tolerance for water quality and needs water treatment plant**

Comparison between Water tube and Fire tube boiler

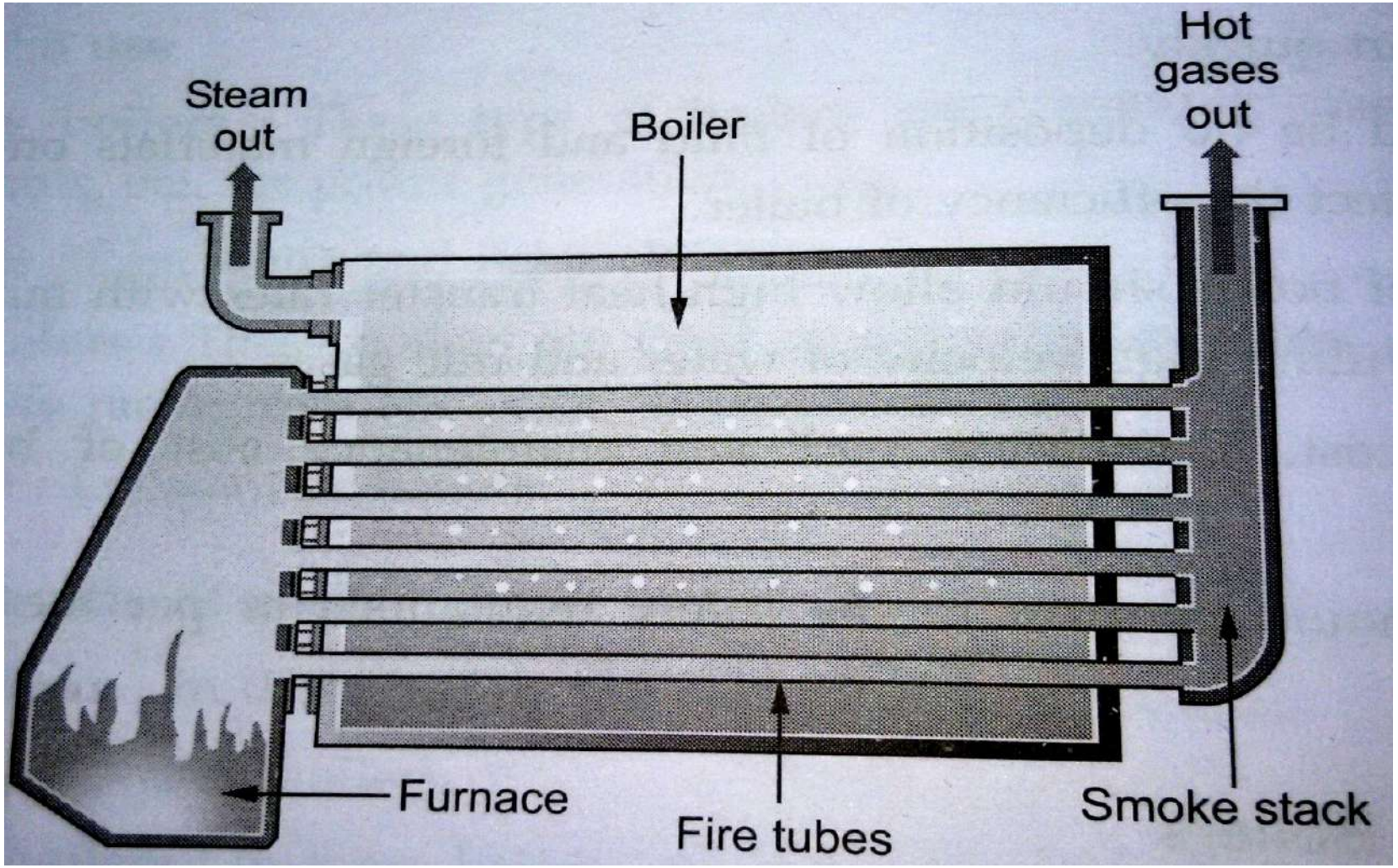
Fire tube boiler	Water tube boiler
Hot flue gases flow inside the tube and the water outside the tube	Water flows inside the tube and the flue gases outside the tube.
This boiler pressure is limited up to 20 bar. These boilers are generally low or medium pressure boiler.	This boiler pressure is up to 70-100 bar. So these boilers are generally high pressure boiler
Fire tube boiler have lower rate of steam production compare to water tube.	It has higher rate of steam production.
These boilers are almost internally fired. Furnace is placed at the one end of fire tube.	These boilers are generally externally fired.
It is suitable for the production work like sugar mill, textile industries.	It is suitable for large power plant.
Risk of explosion is lower due to low pressure.	Risk of explosion is higher due to high pressure boiler.
It is difficult to repair and cleaning.	It is easily clean and repairable due to externally fired.

Fire tube boiler	Water tube boiler
This boiler is difficult to construct.	This is simple in construction.
The efficiency of fire tube boiler is less compare to water tube. It will increase by using other accessories.	This boiler is more efficient.
The treatment of water is not necessary.	The water flows through small diameter tube. So water is treated before entering into the tube otherwise it will jam the tube.

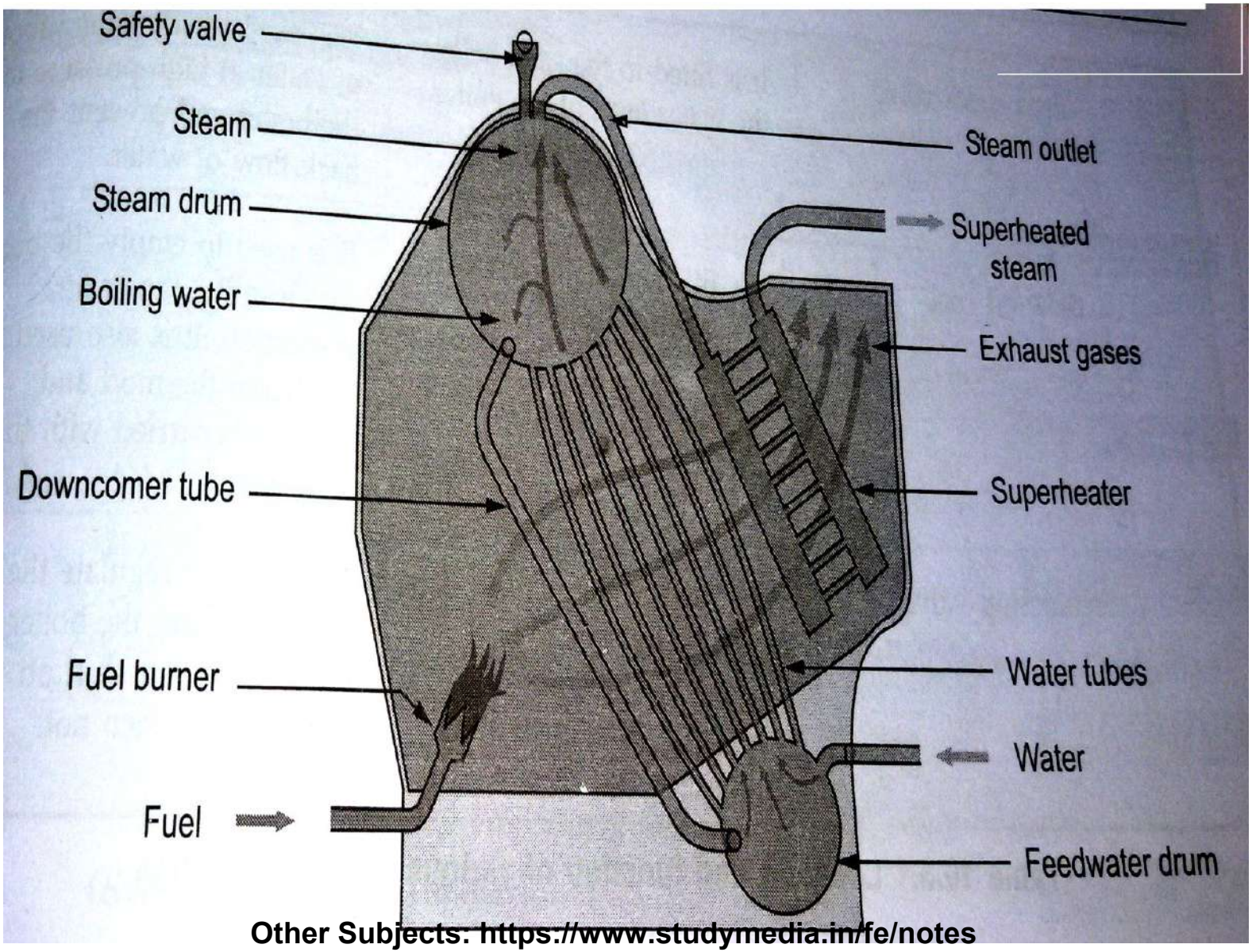
Package Type boiler

- Package boilers are widely used in pharmaceutical, food and ceramic industries.
- These boilers requires less fuel and electricity for their operation.
- Typical package boiler is either water tube or fire tube with a steam generation capacity of 5-25 tonnes per hour.
- Most commonly used fuels for these boilers are heavy oil, light oil or gas.

Package Type Fire tube boiler



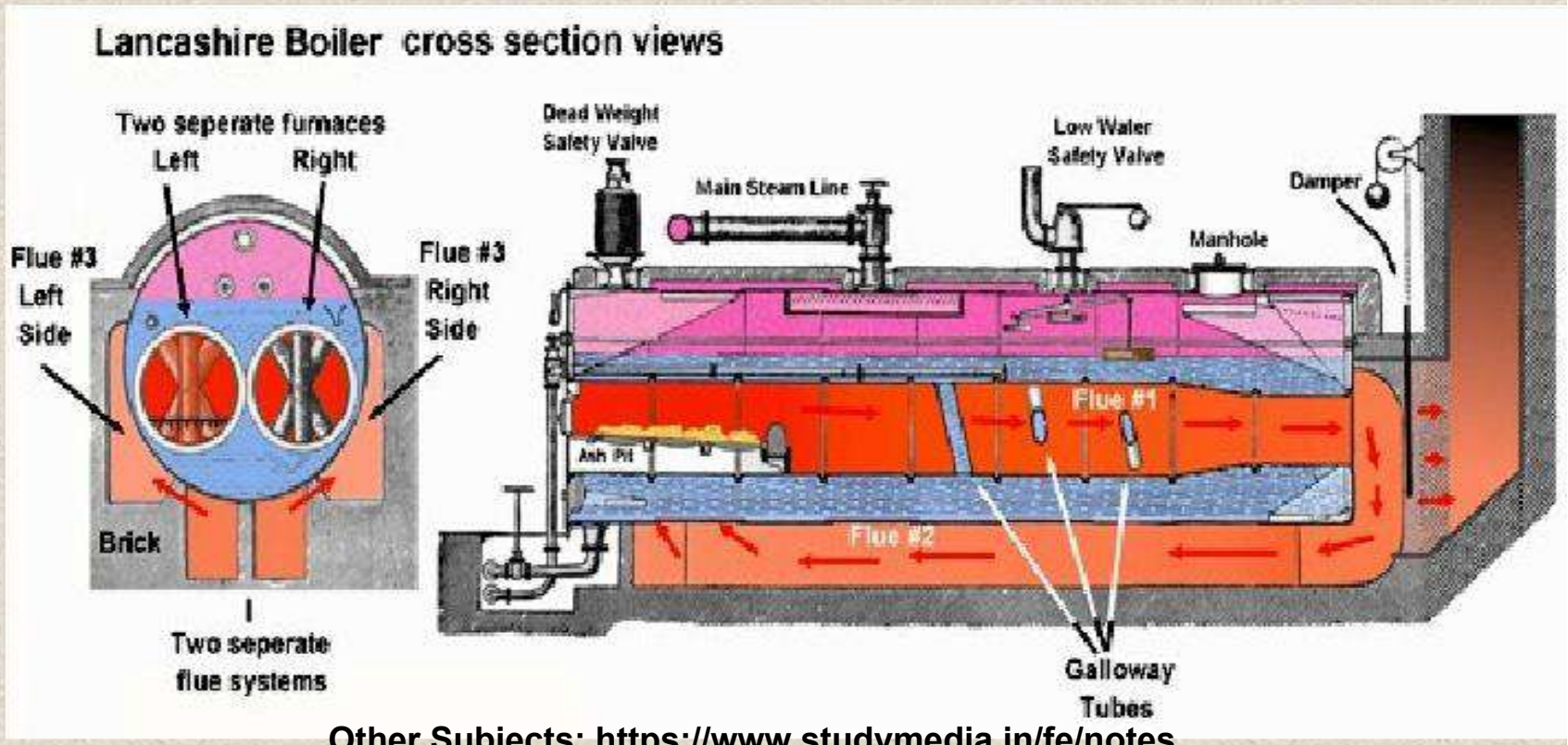
Package Type Water tube boiler



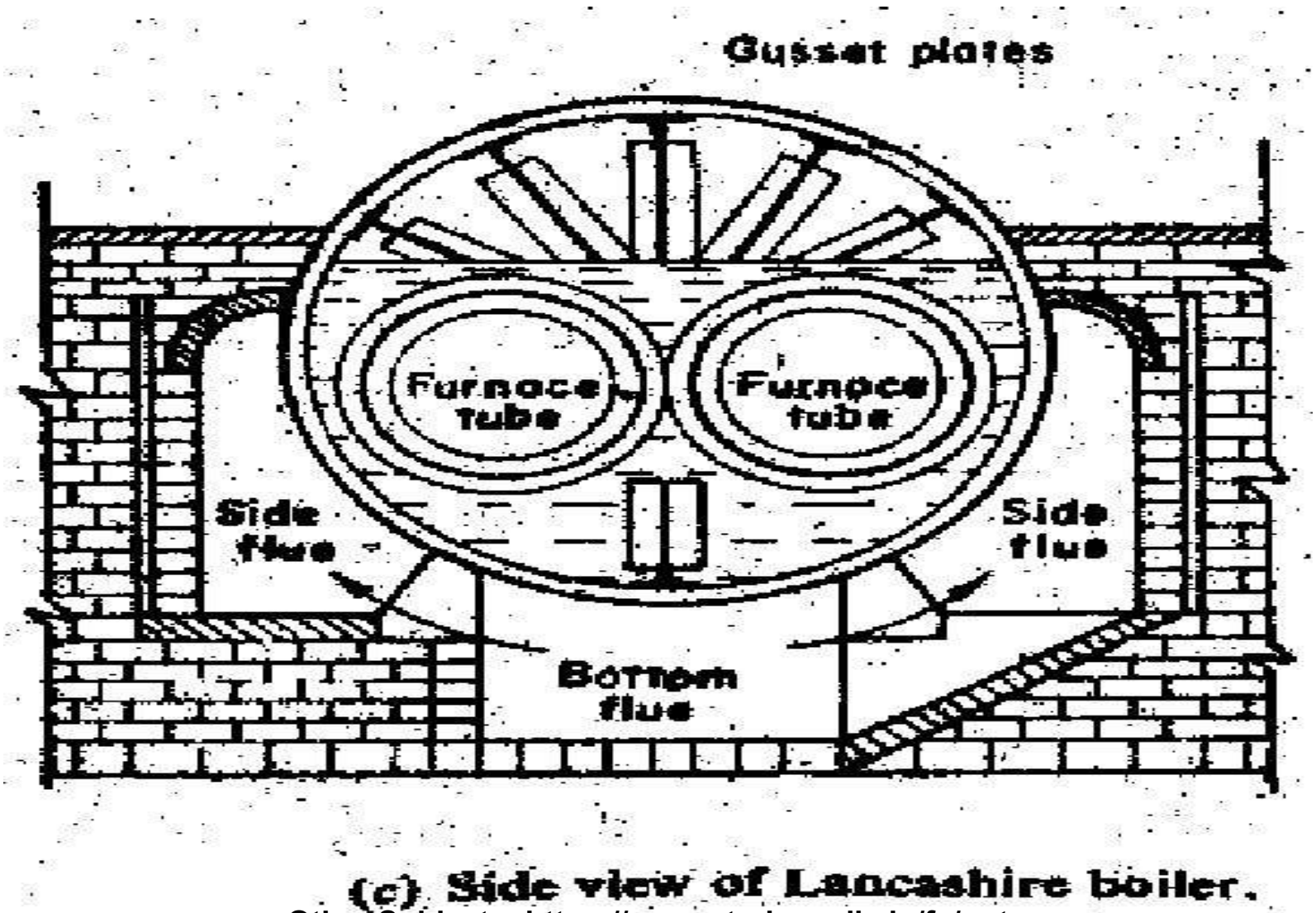
LANCASHIRE BOILER

Fire – tube Boilers

Lancashire Boiler



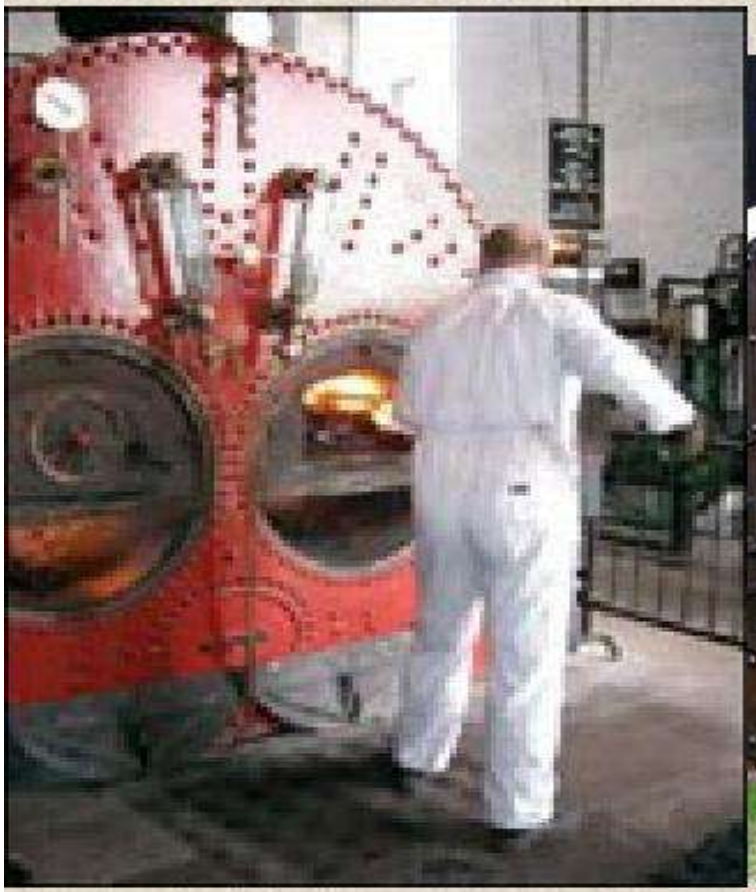
LANCASHIRE BOILER



(c) Side view of Lancashire boiler.

LANCASHIRE BOILER

Fire – tube Boilers



Lancashire Boiler

LANCASHIRE BOILER

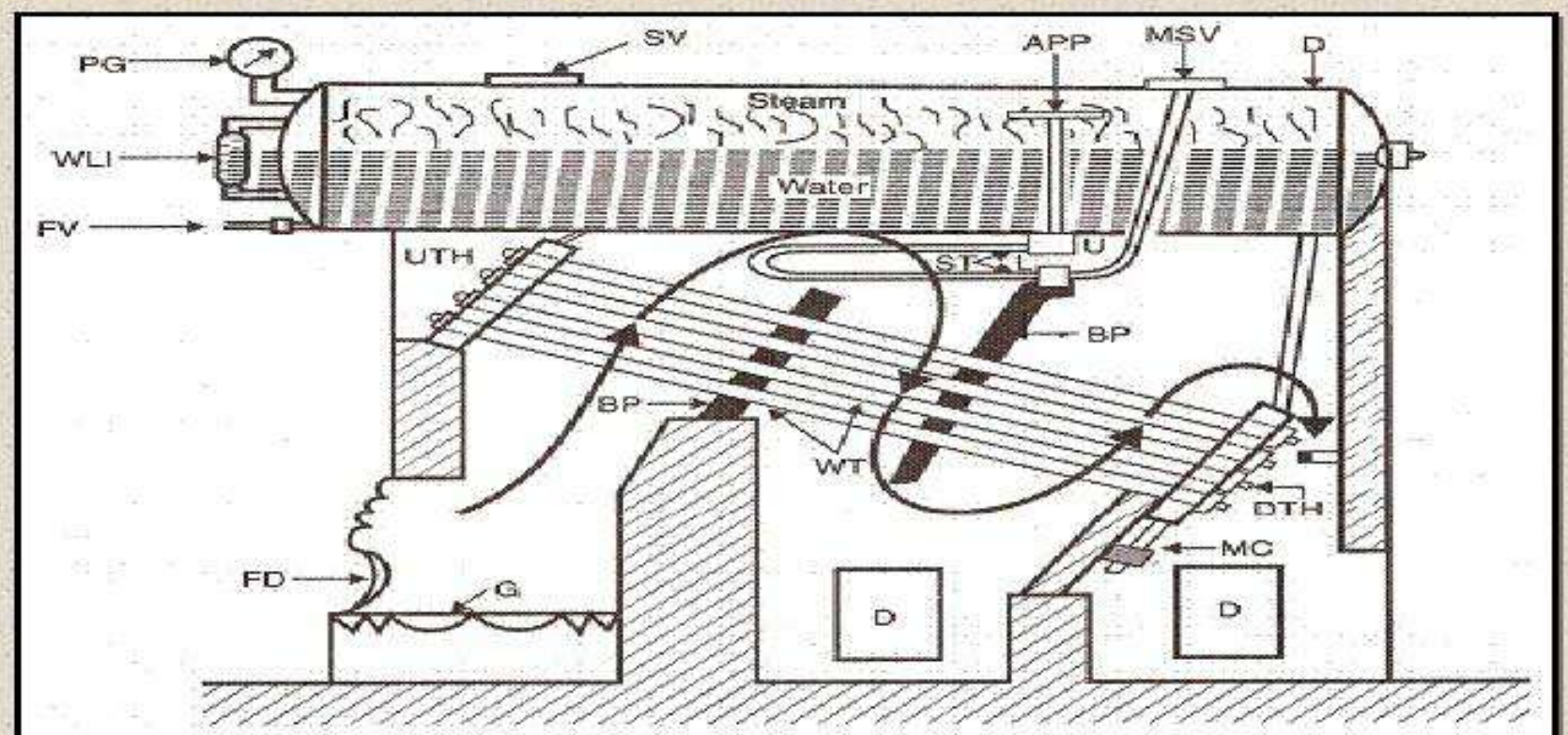
- Used where requirement of power & steam pressure are moderate.
- Consist of cylindrical shell 2 to 3 m in dia. & 7.25 to 9 m in length set in brick work.
- Consist of 2 large horizontal flue gas pipes running parallel & passing through it.
- Each pipe has a grate towards the front of shell supported by brick arch

LANCASHIRE BOILER

- Below grate is ash pit & water surrounds the pipe.
- Flue gases from grate pass through flue gas pipes & then down to bottom flue.
- Then moves to front in path provided by shell & brick work.
- At this junction ,these gases divide into 2 parts & flow through side flue along the shell in the direction towards back end of shell.
- From side flue gas enters the main flue from where they are taken to chimney.

BABCOCK-WILCOX BOILER

BABCOCK WILCOX BOILER



D = Drum
DTH = Down take header
WT = Water tubes
BP = Baffle plates
D = Doors
G = Grate
FD = Fire door
WLI = Water level indicator

PG = Pressure gauge
ST = Superheater tubes
SV = Safety valve
MSV = Main stop valve
APP = Antipriming pipe
L = Lower junction box
U = Upper junction box

BABCOCK-WILCOX BOILER

BABCOCK-WILCOX BOILER

BABCOCK-WILCOX BOILER

- Consist of no. of inclined water tubes connected between uptake header & downtake header.
- Whole combustion chamber is divided into number of parts with the help of baffles.
- Hot gases first move from furnace upwards between water tubes
- Then move downward & upward between baffles over the tubes

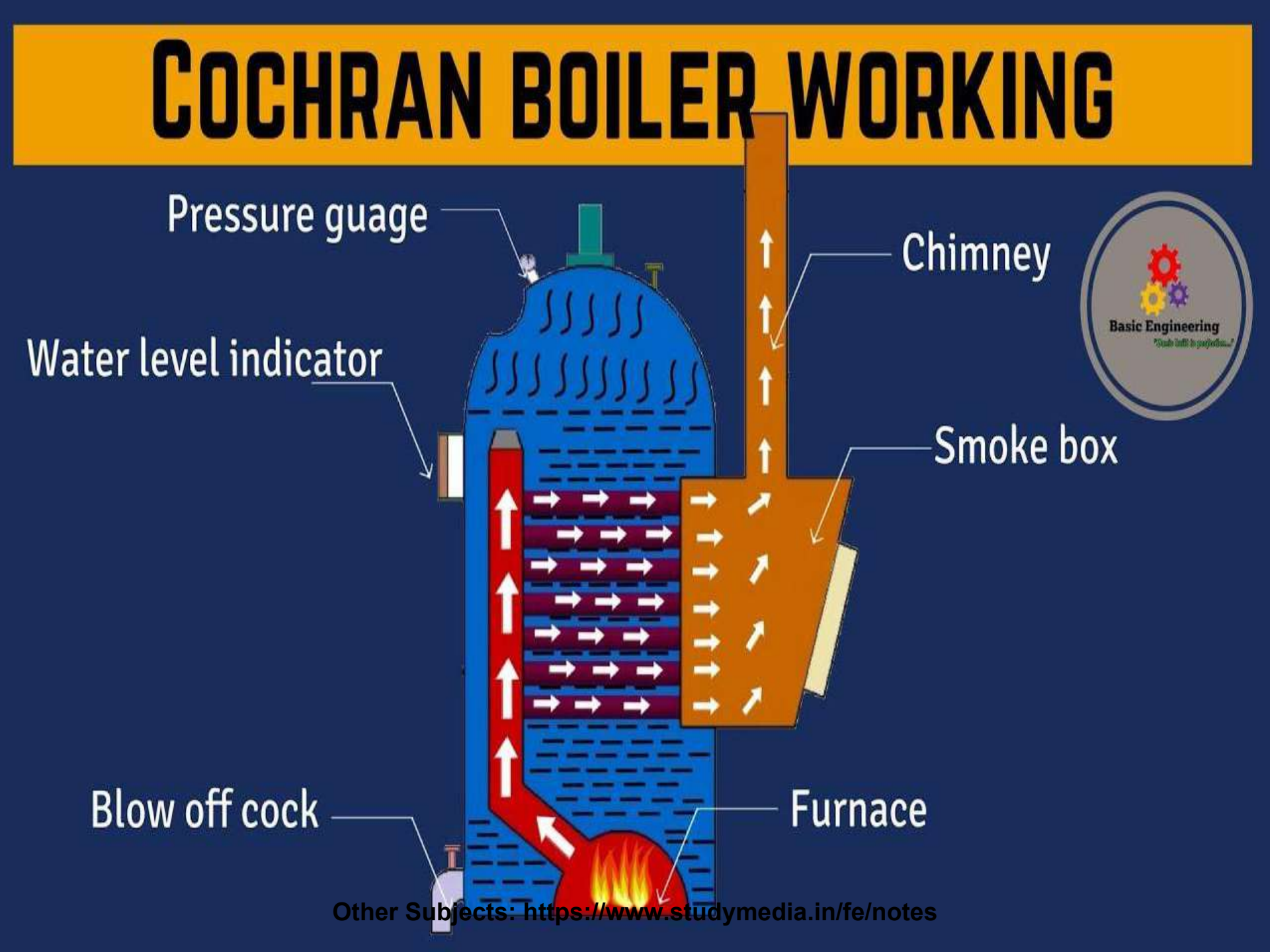
BABCOCK-WILCOX BOILER

- Finally gases are exhausted to chimney through damper.
- Feed water enters the front of drum & travels to back part of drum & then descends through vertical tube to downtake header
- Then water enters into water tubes to uptake header & then to drum.
- Water tubes near uptake header are in contact with hoter flue gases.

BABCOCK-WILCOX BOILER

- Water in uptake header rises due to decreased density & enters the drum –replaced by colder water from downtake header.
- Water continues to circulate till it evaporates.
- This type of circulation of water due to density difference is called free circulation.
- Superheating of steam takes place in superheater.

COCHRAN BOILER WORKING



BOILER MOUNTINGS

- Various items mounted on boiler for its safe operation and maintenance.

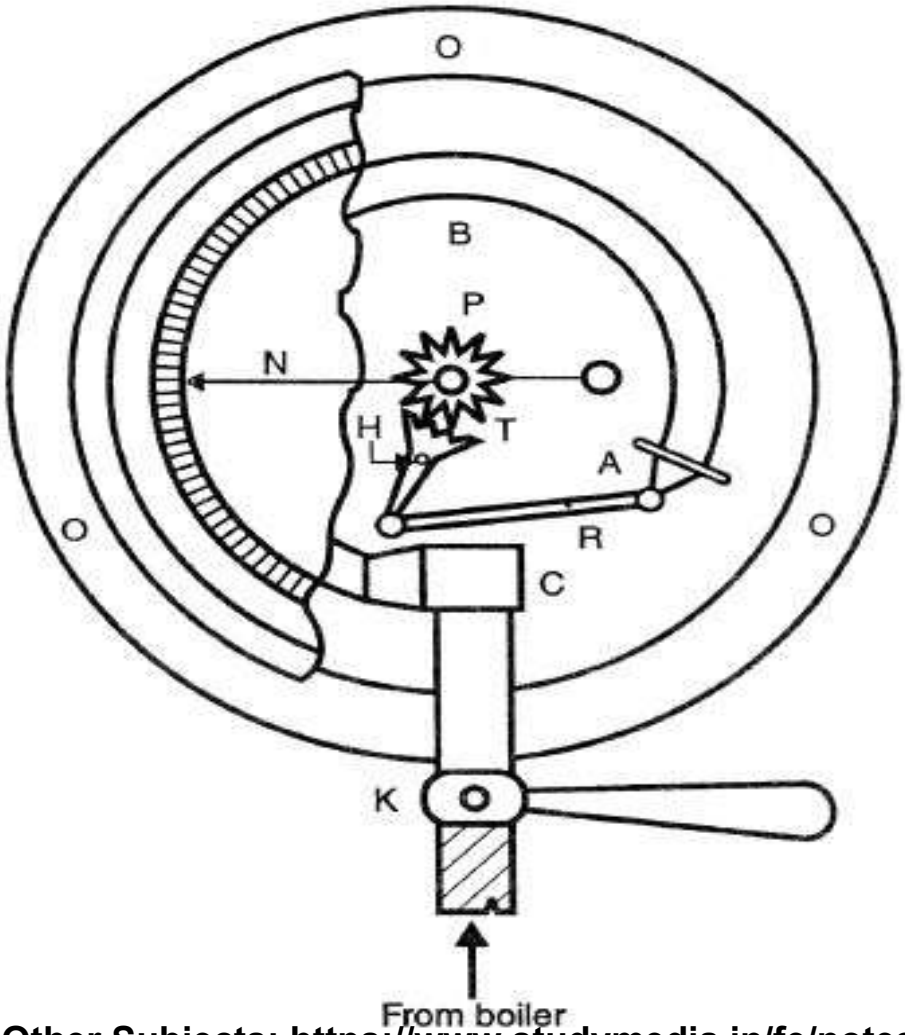
- Water level indicators
- Safety valves
- Pressure gauge
- Stop valve
- Feed check valve
- Blow off cock

BOILER ACCESSORIES

- Used for efficient operation and smooth working.

- Water feeding devices
- Superheater
- Economiser
- Air preheater

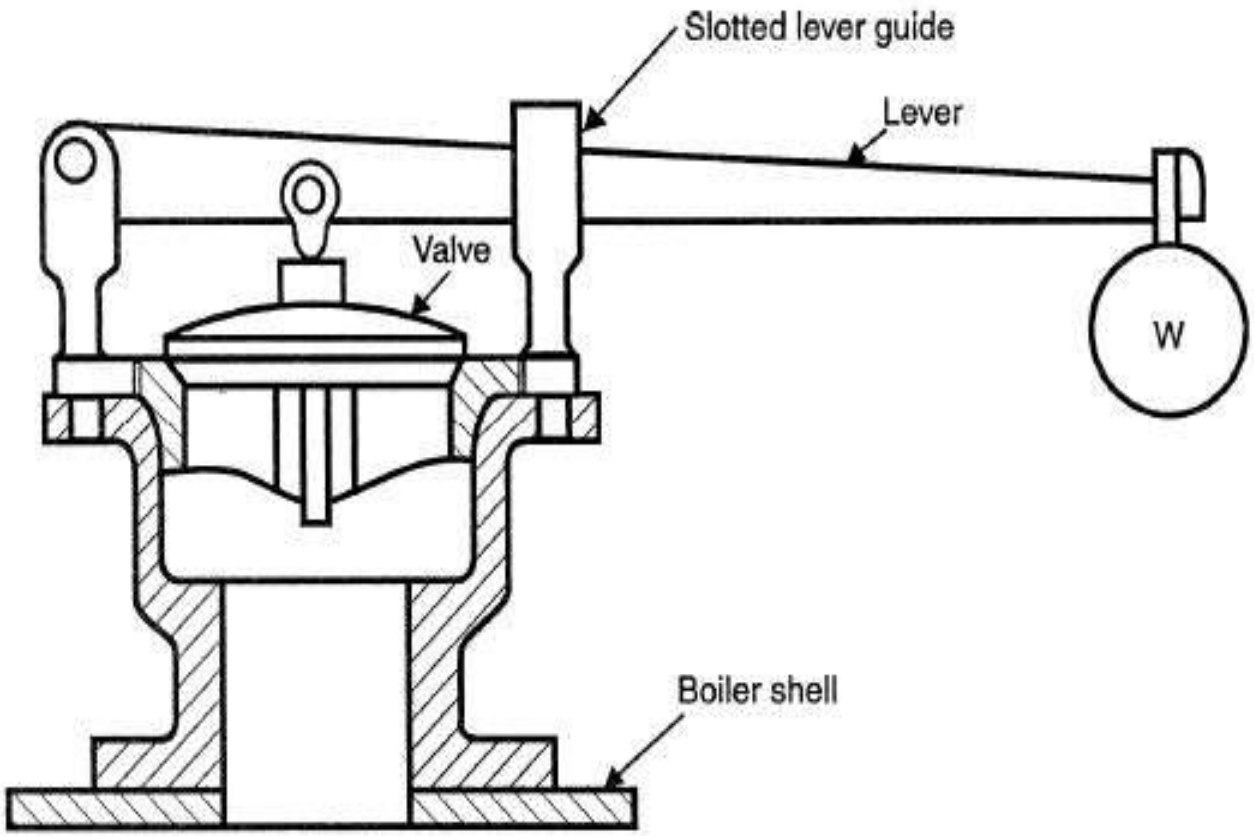
PRESSURE GAUGE



PRESSURE GAUGE

- **Used to record pressure of steam in boiler.**
- Bourdons pressure gauge
- It consist of bourdon tube whose one end is connected to pointer and other end is connected to siphon pipe.
- Steam pressure which acts on water is finally transmitted to bourdon tube.
- Tube being fixed at one end ,Its other end moves outward
- This movement is proportional to difference in pressure.

LEVER SAFETY VALVE



LEVER SAFETY VALVE

- **Used to prevent the boiler from bursting if pressure exceeds designed pressure.**

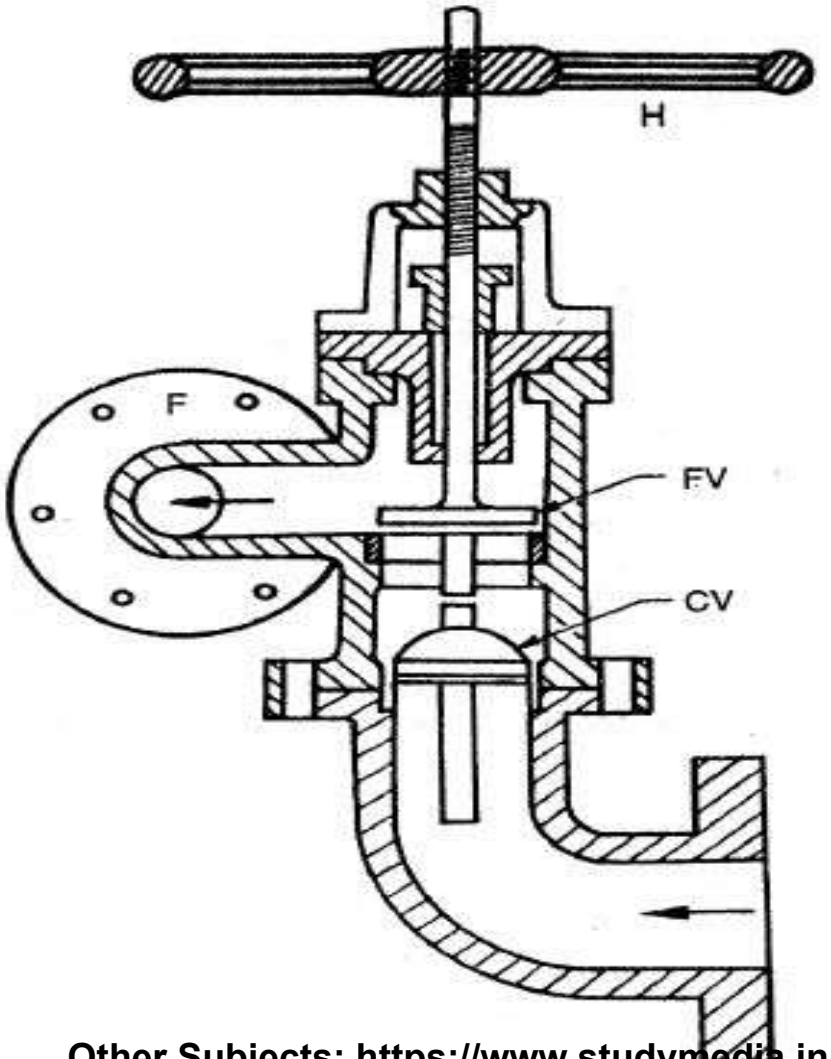
- Consist of block on which valve seat is screwed.
- Block is connected to steam boiler

- Lever rests on bridges fixed to block & at one end of lever a weight is attached & other end is hinged.

- Required weight is determined to keep the valve closed up to desgnedpressure.

- If steam exceeds the valve is lifted from seat & steam escapes to surrounding.

FEED CHECK VALVE

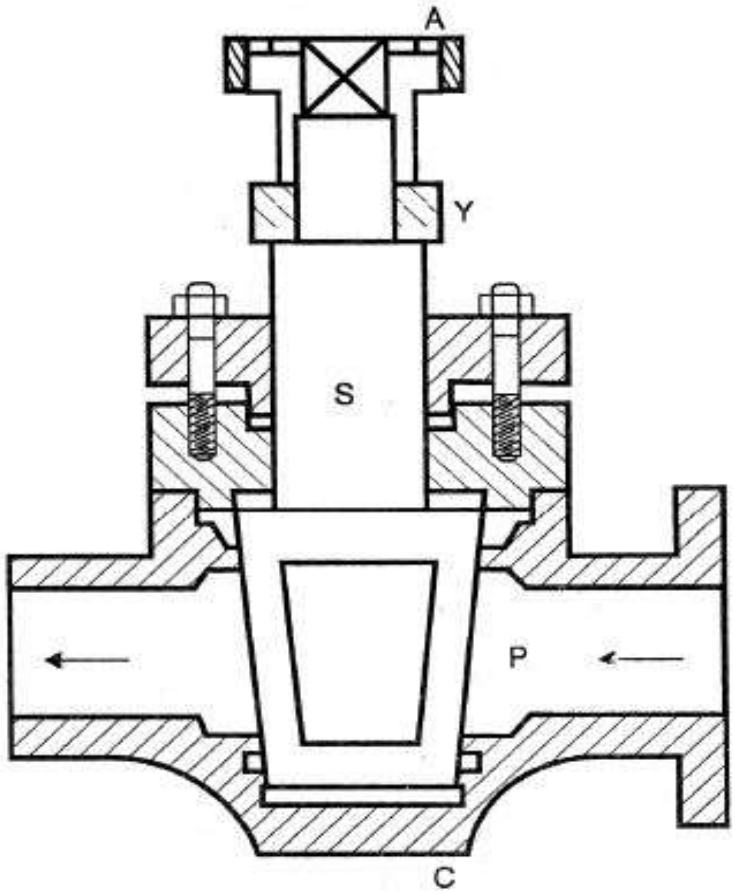


FEED CHECK VALVE

FEED CHECK VALVE

- **Non-return valve which permits flow of water in one direction only.**
- It consist of check valve which rests on its valve seat
- Check valve can be kept in closed position by pressing it down by spindle operated by hand wheel.
- Before starting the feed pump spindle is lifted from valve with the help of hand wheel.

BLOW-OFF-COCK VALVE



C = Casing
S = Shank
P = Plug

A = Vertical slots
Y = Yoke

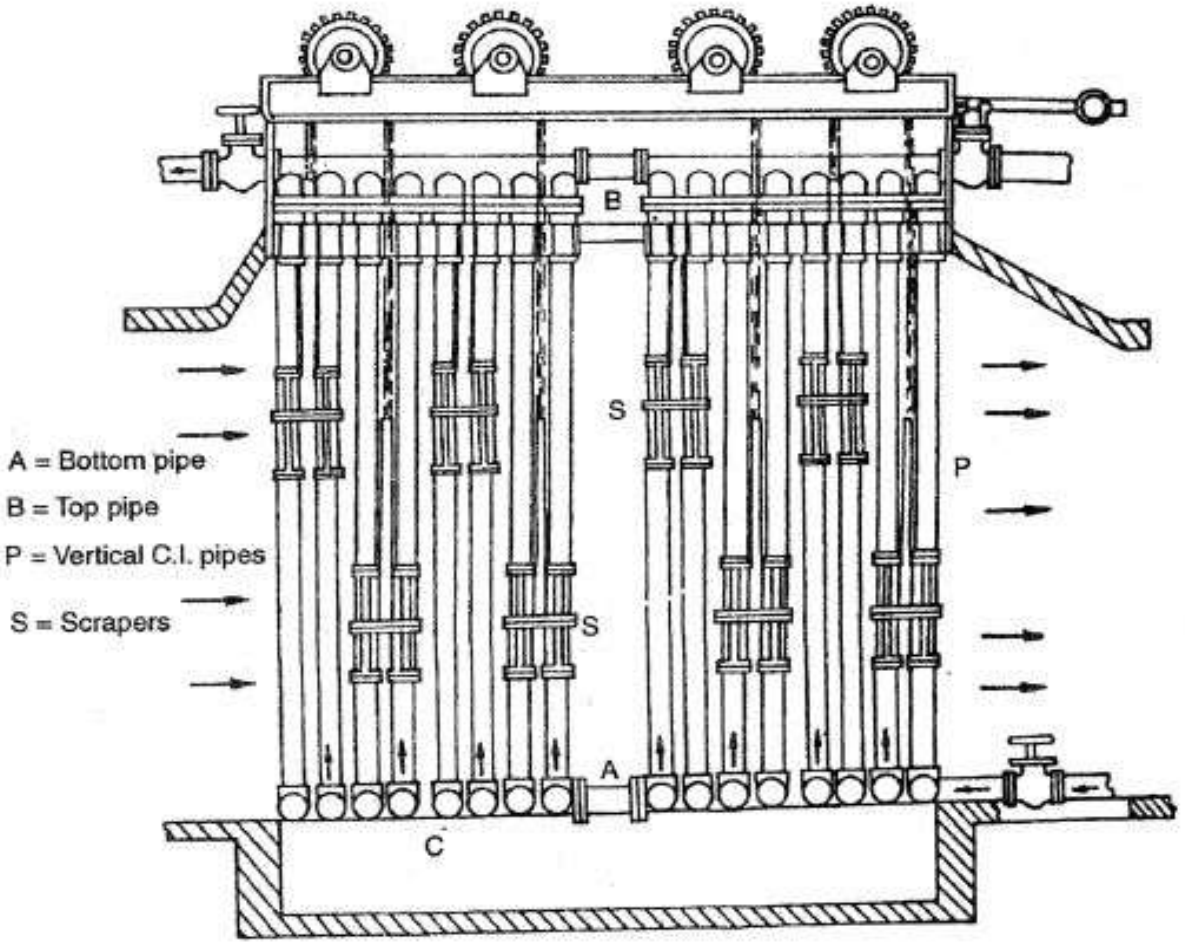
BLOW-OFF-COCK VALVE

- **It is used to remove mud and sediments**
  .

- Also used to remove water when boiler is subjected to inspection , repair and maintenance.

STOP VALVE

ECONOMISER



A = Bottom pipe
B = Top pipe
P = Vertical C. I. pipes
S = Scrapers

ECONOMISER

- **An economizer is a heat exchanger, used for heating the feed water before it enters the boiler.**
- It helps in improving the boiler efficiency.
- Consists of large number of vertical tubes made of C.I joined with horizontal pipes at top & bottom.
- Cold feedwater is pumped into horizontal pipe through stop valve.
- Hot flue gases from boiler pass over vertical tubes and transfer heat to cold water rising in these tubes.
- Hot feed water is supplied to boiler from top horizontal pipe
- Blow off cock is mounted to remove any mud or sediments.

AIR PREHEATER

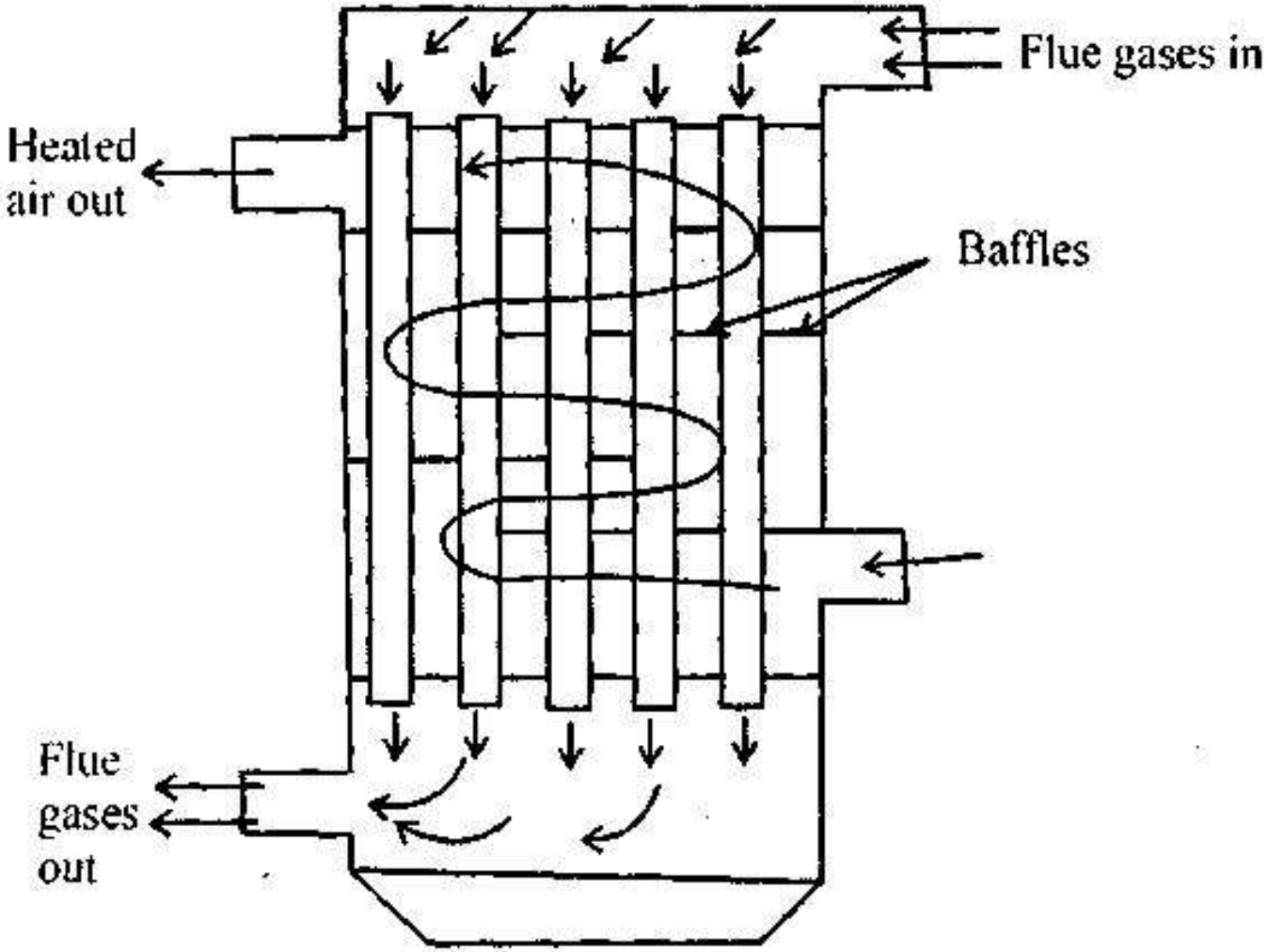


Fig. Tubular Type Air Preheater

AIR PREHEATER

- **Utilizes waste heat of flue gases leaving the economiser to heat the air to be supplied to the boiler**

- Flue gases are finally discharged to chimney from air preheater.

- It improves the combustion efficiency.

- Hot flue gases pass through tubes & cold air is passed over these tubes

Engines

- Engine:

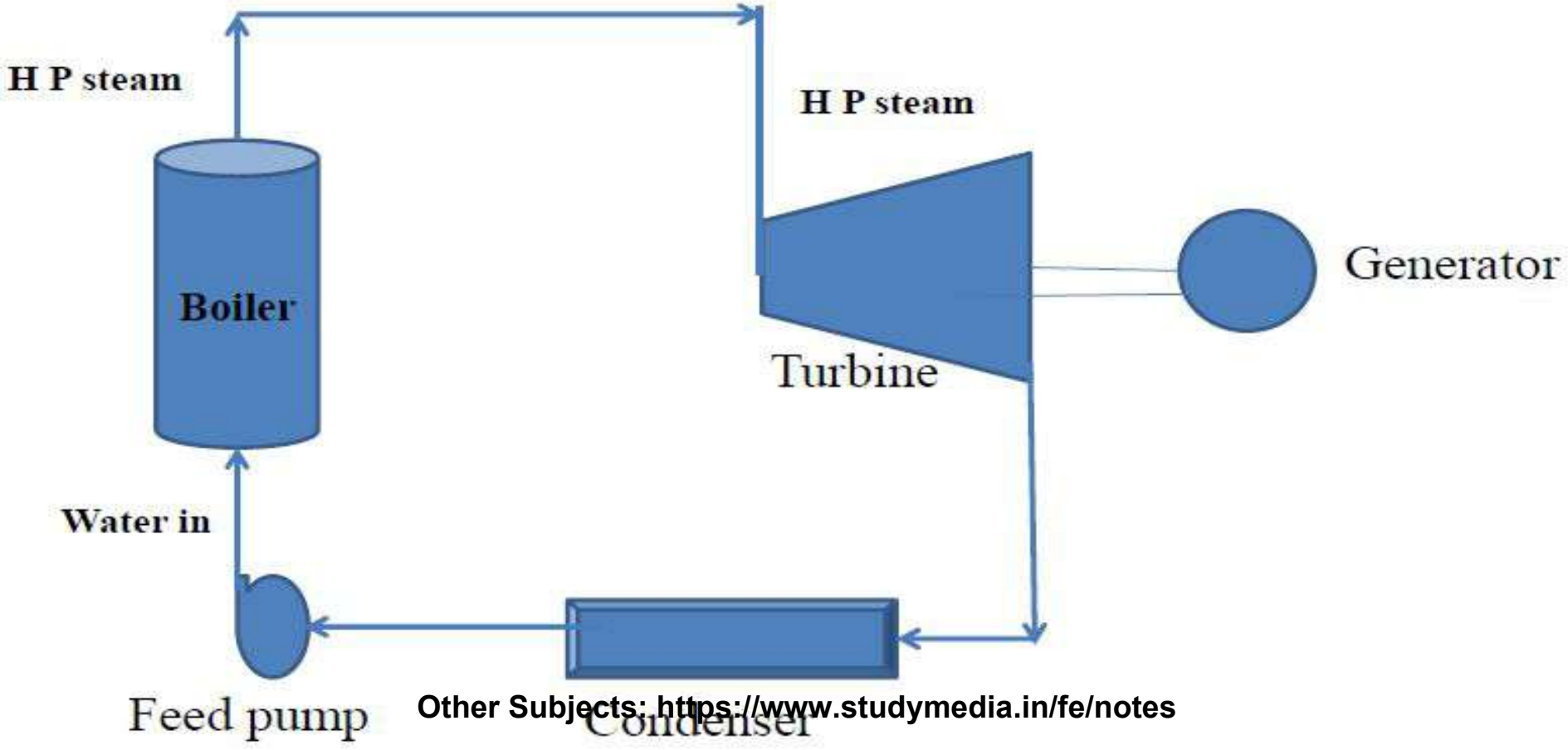
  Engine is a device, which converts heat energy into mechanical energy.

Engines are classified into two types

1) External Combustion Engines
2) Internal Combustion Engines

External combustion engines

Combustion of fuel takes place outside the engine cylinder.



Internal Combustion Engines

- Combustion of fuel takes place inside the cylinder itself with air inducted from atmosphere.

- The chemical energy of fuel released raises the pressure and temperature of the products of combustion.

- These hot gases are substantially expanded to develop the mechanical power and rejected to atmosphere.

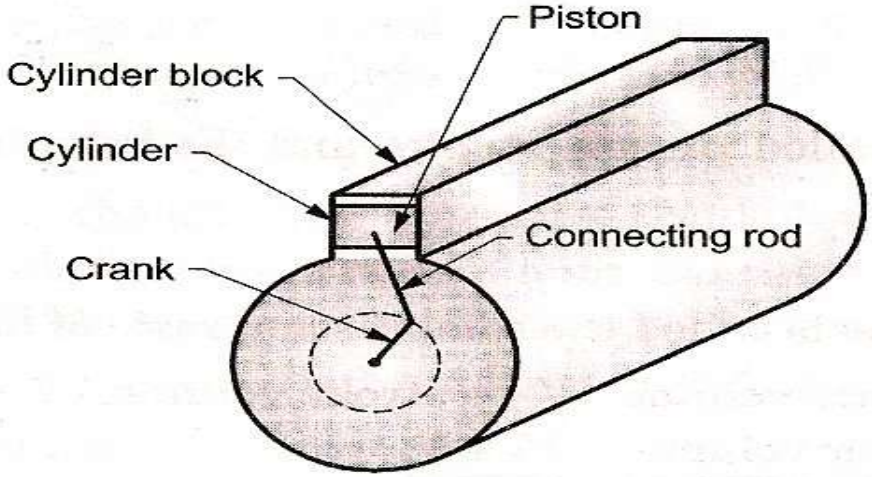
Classification of I.C.Engine

1) Based on number of stroke per cycle.
   a) four stroke cycle engine
   b) Two stroke cycle engine

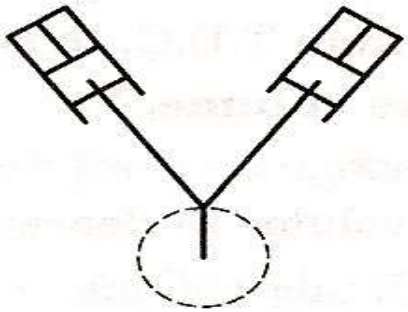
2) Based on cycle of combustion.
   a) Otto cycle engine
   b) Diesel cycle engine
   c) Dual combustion cycle engine

3) Based on number of cylinder
   a) Single cylinder engine
   b) Multicylinder engine

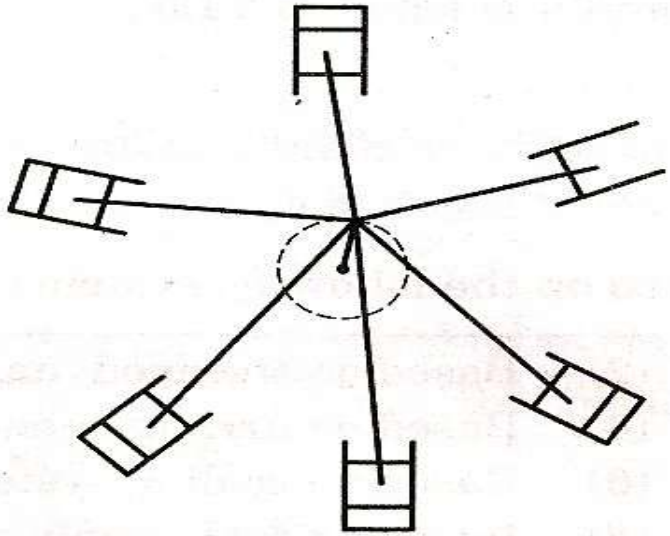
4) Arrangement of cylinders



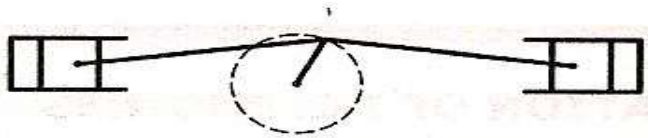
(a) In-line engine



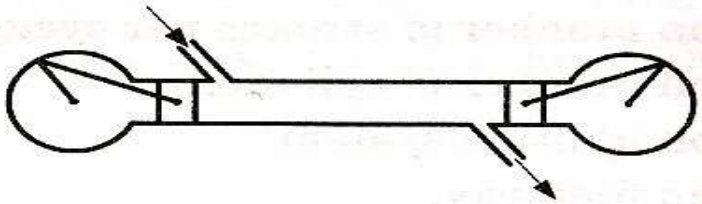
(b) V-engine



(c) Radial engine



(d) Opposed cylinder



(e) Opposed piston

5) Method of ignition of fuel

a) Spark ignition (S.I) engine

b) Compression ignition (C.I) engine

6) Based on fuel used

a) petrol engine

b) Diesel oil engine

c) gas engine

d) Light oil (kerosene) engine

7) Method of cooling the cylinder

a) air cool engine

b) Water cool engine

8) Based on fuel supply system

a) Carburetor engine

b) Air injection engine

c) solid injection engine

9) Their uses

a)Stationary engine

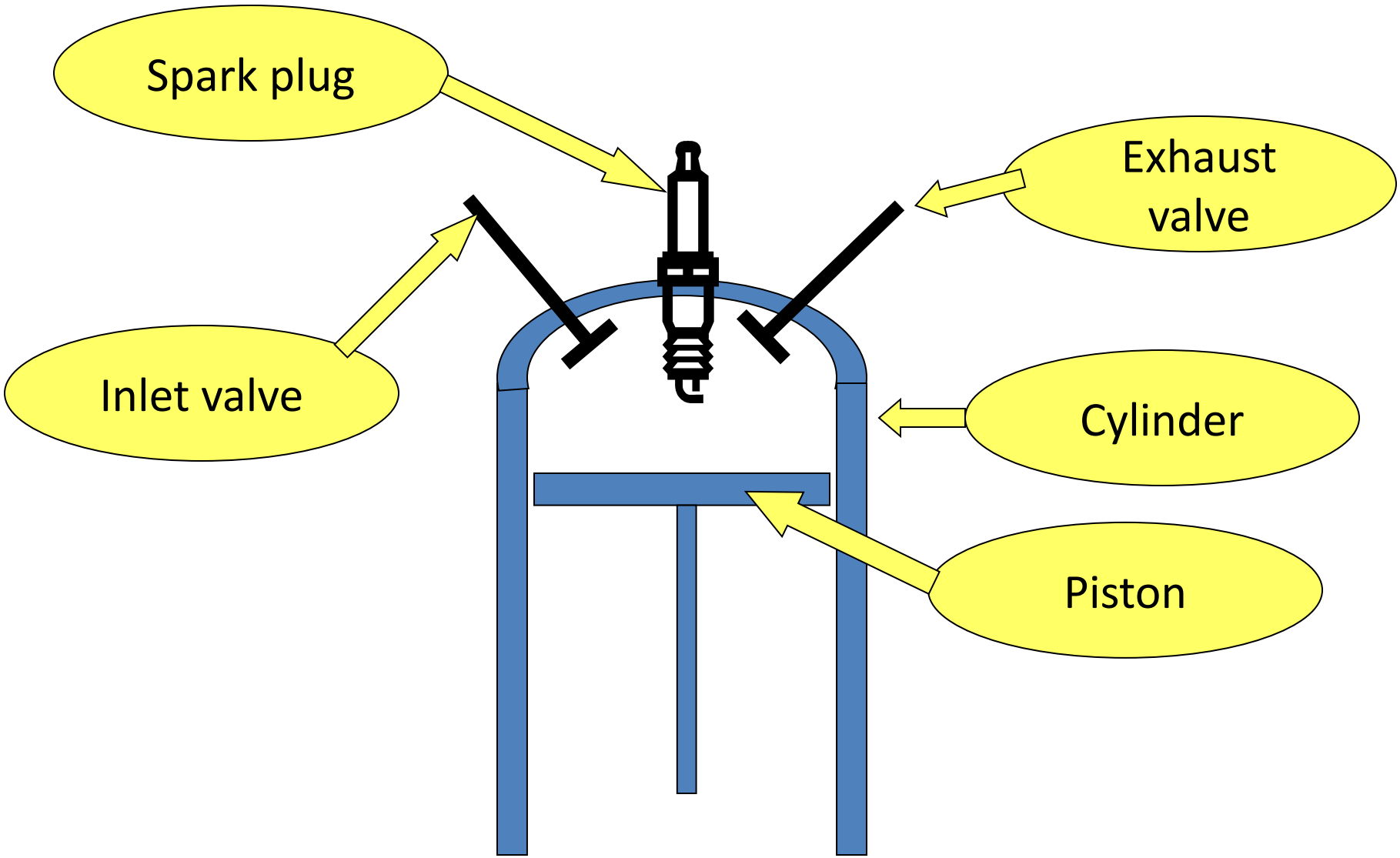
b) portable engine

c) Marine engine

d) Automobile engine

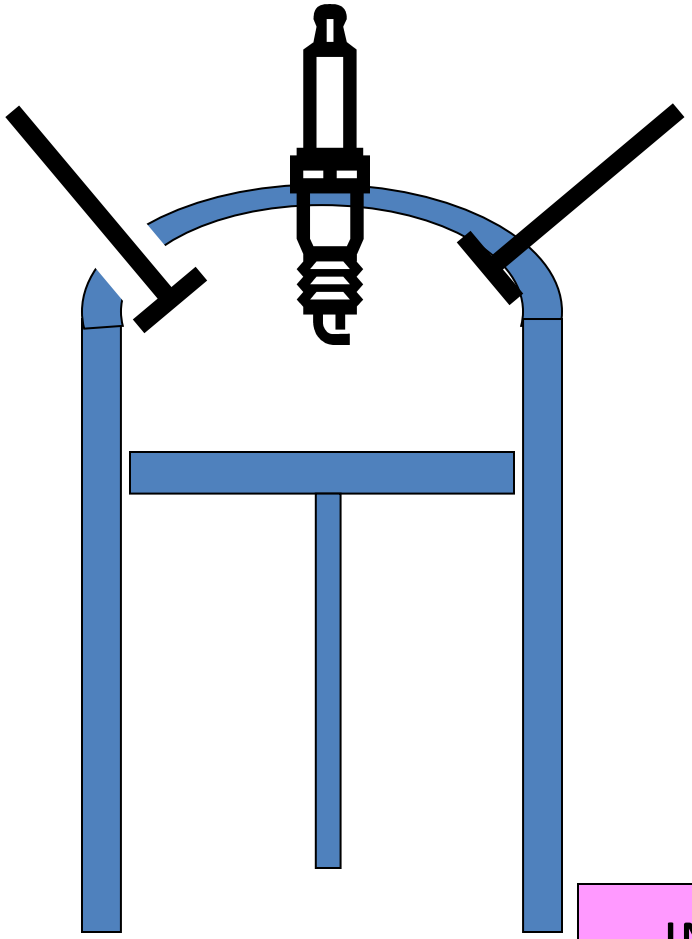
e) Tractor engine

The four-stroke engine



The four-stroke engine

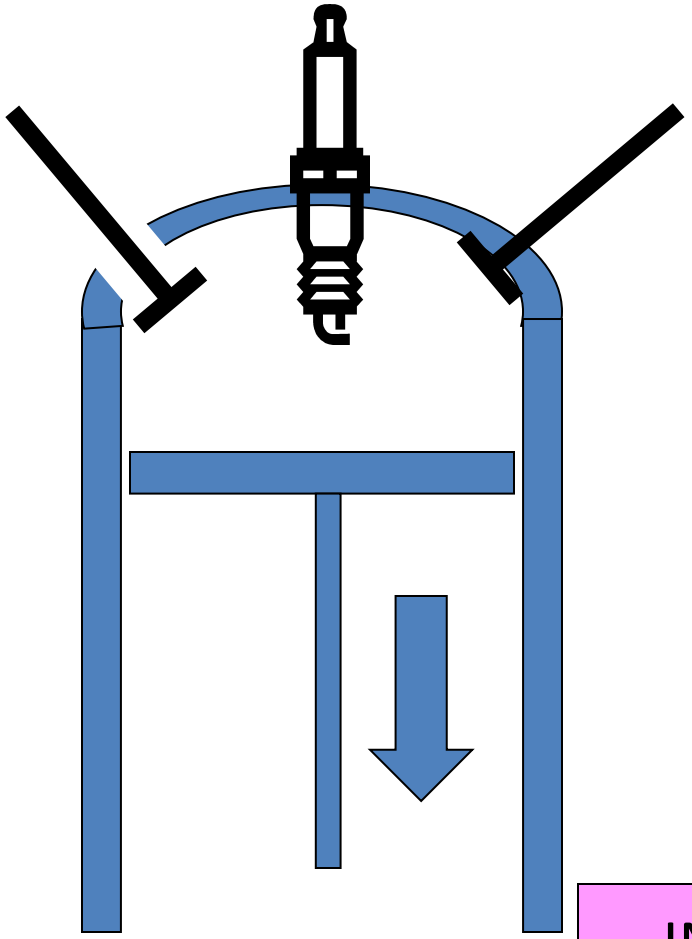
Inlet valve opens



INDUCTION STROKE

The four-stroke engine

Inlet valve open



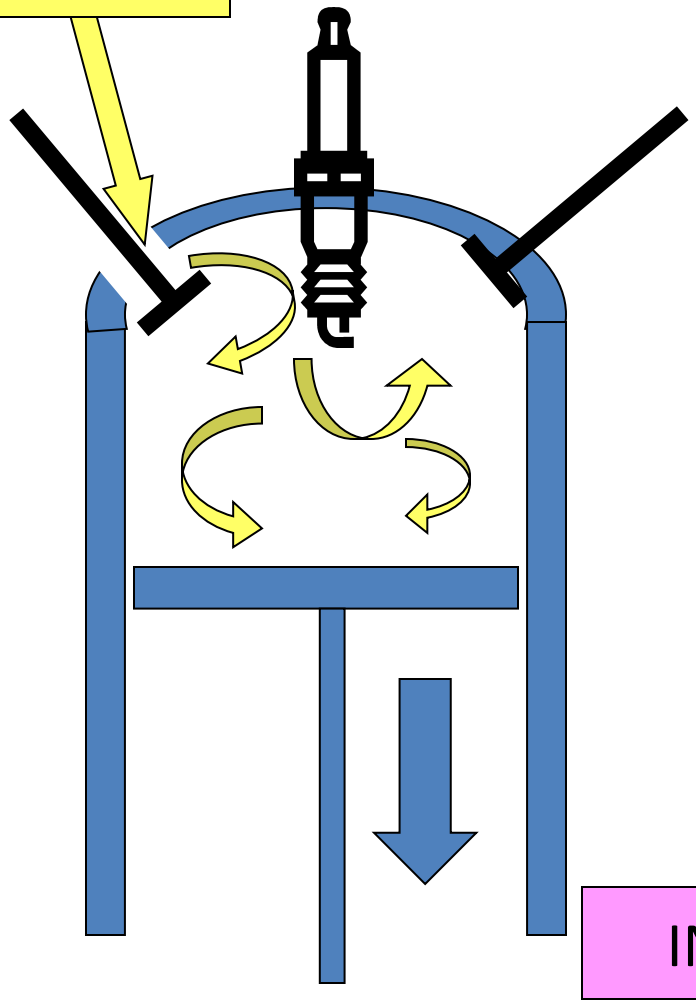
INDUCTION STROKE

Piston down

The four-stroke engine

Air/Fuel Mixture In

Inlet valve open

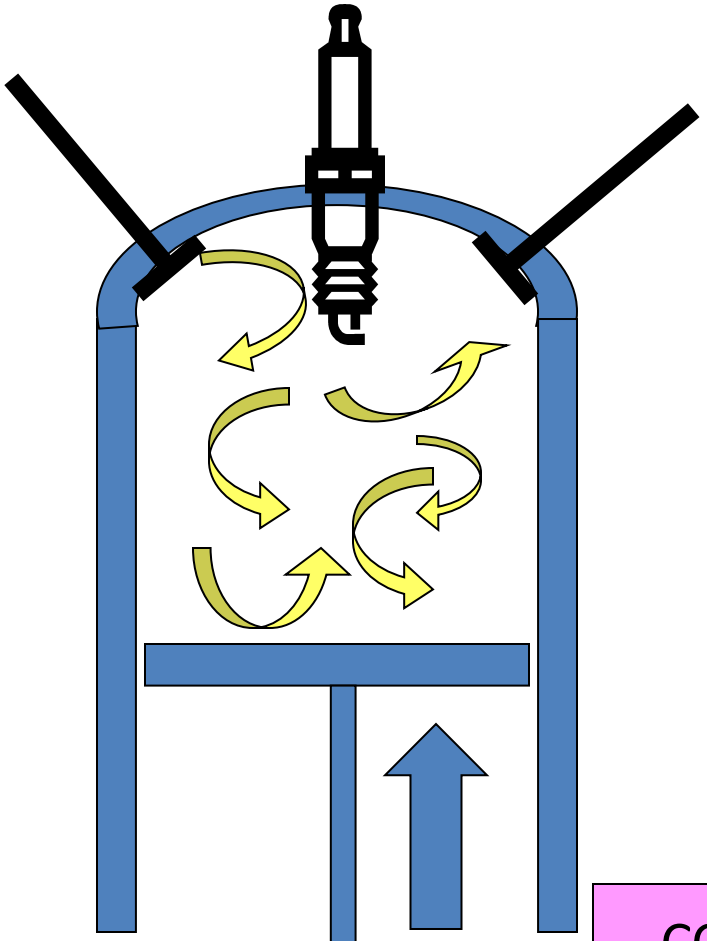


INDUCTION STROKE

Piston down

The four-stroke engine

Inlet valve closes

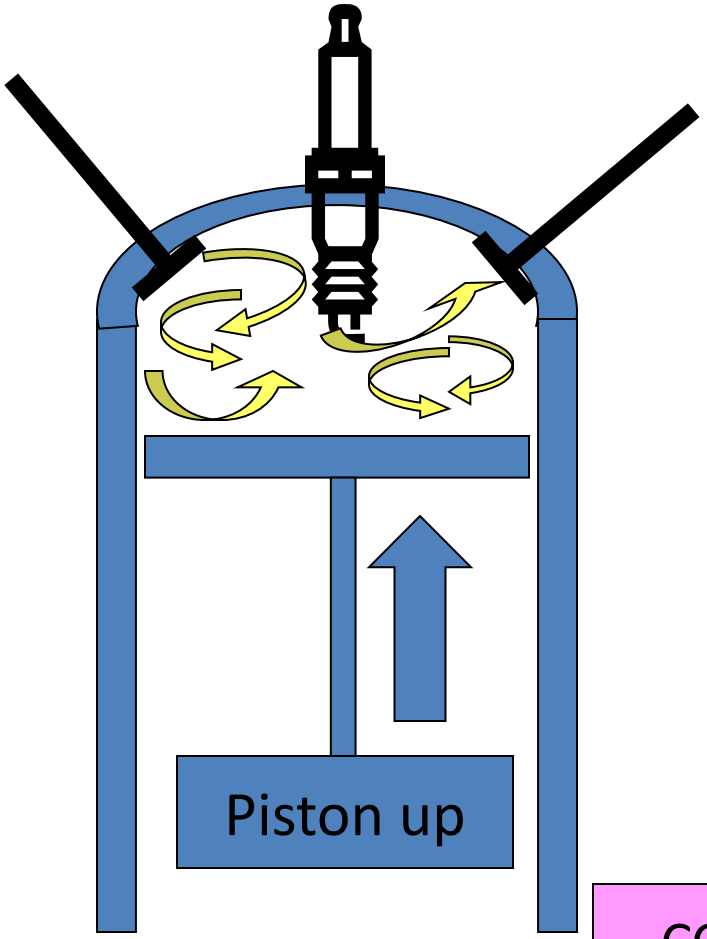


COMPRESSION STROKE

Piston up

The four-stroke engine

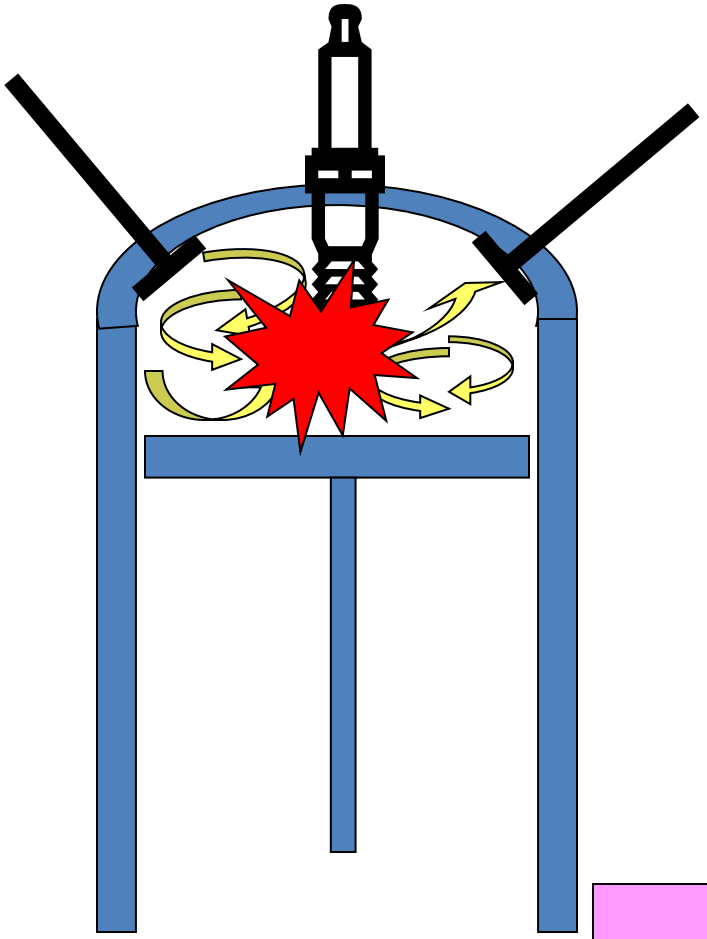
Inlet valve closed



COMPRESSION STROKE

The four-stroke engine

Inlet valve closed

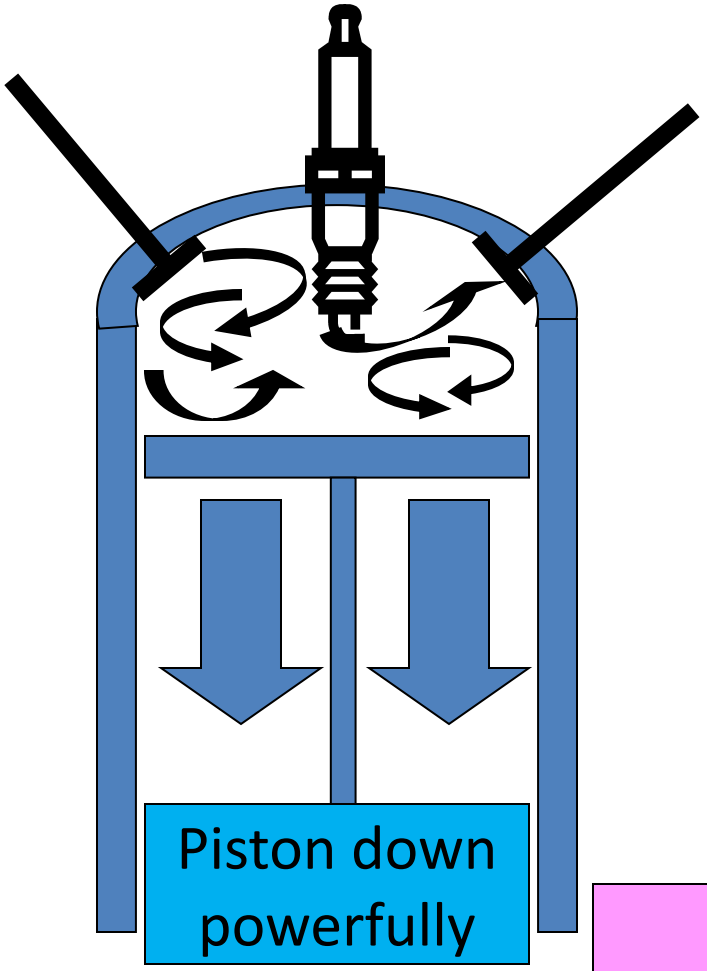


BANG

POWER STROKE

The four-stroke engine

Inlet valve closed

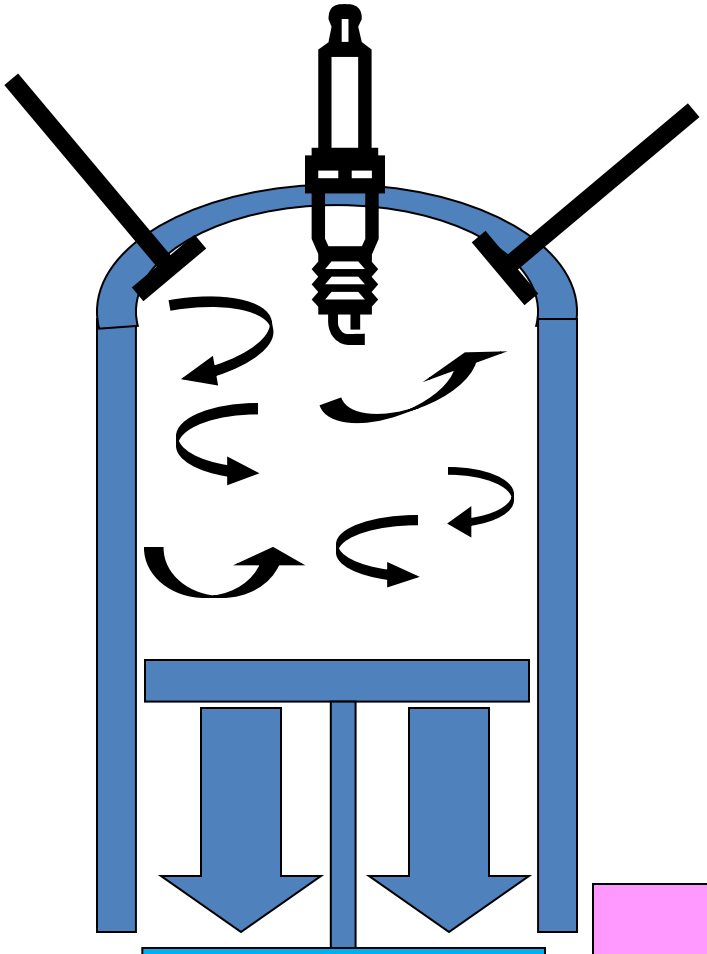


Piston down powerfully

POWER STROKE

The four-stroke engine

Inlet valve closed

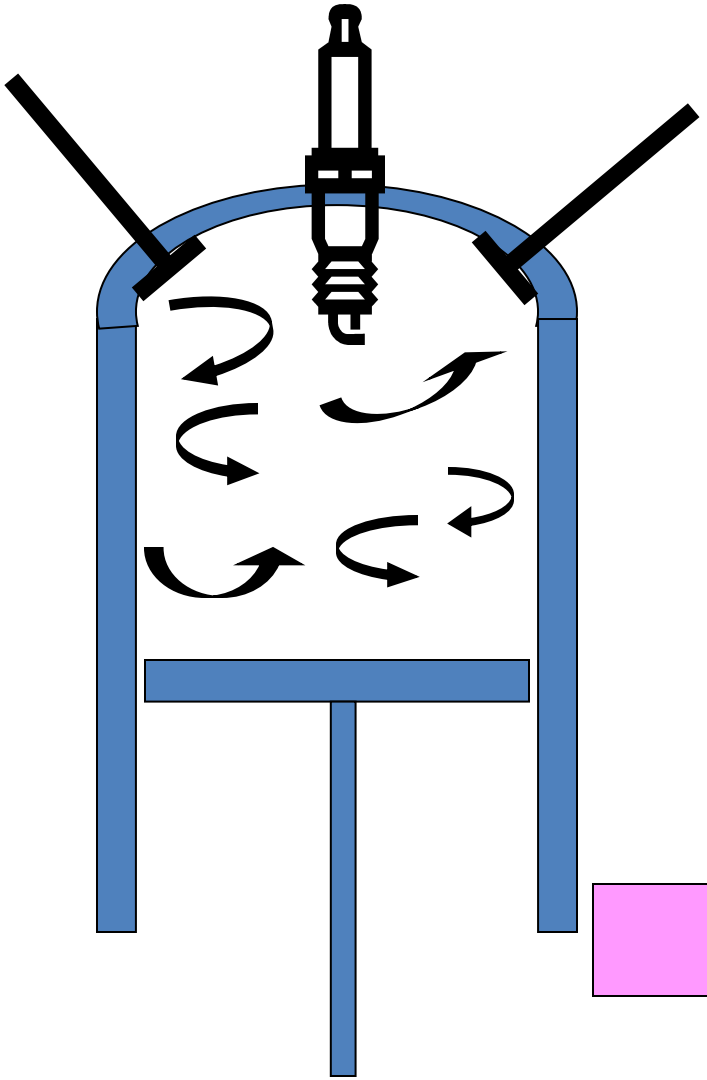


POWER STROKE

Piston down powerfully

The four-stroke engine

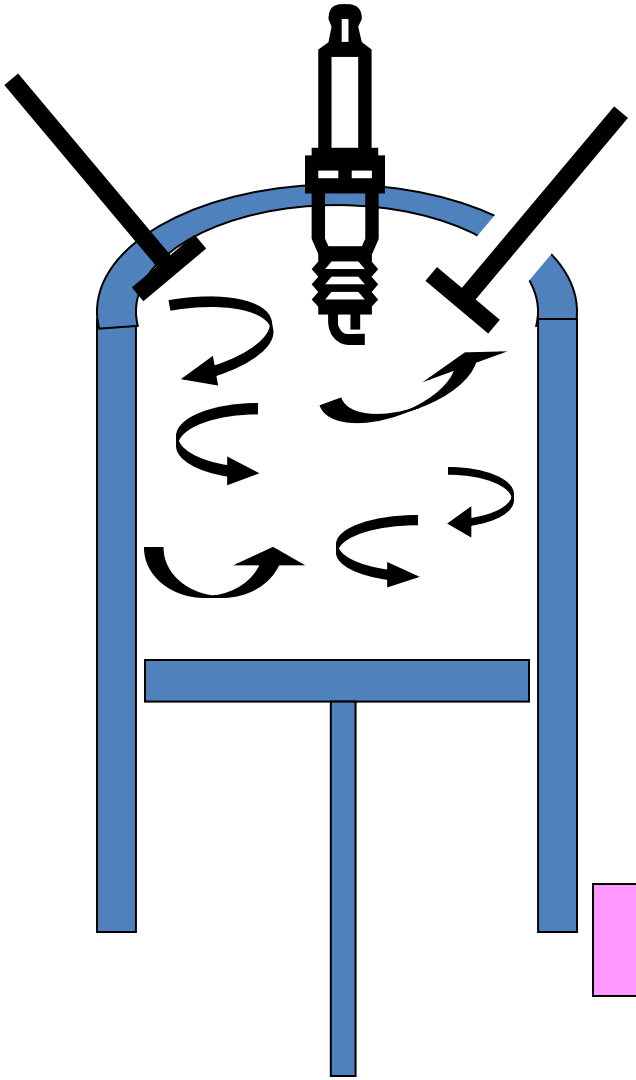
Inlet valve closed



POWER STROKE

The four-stroke engine

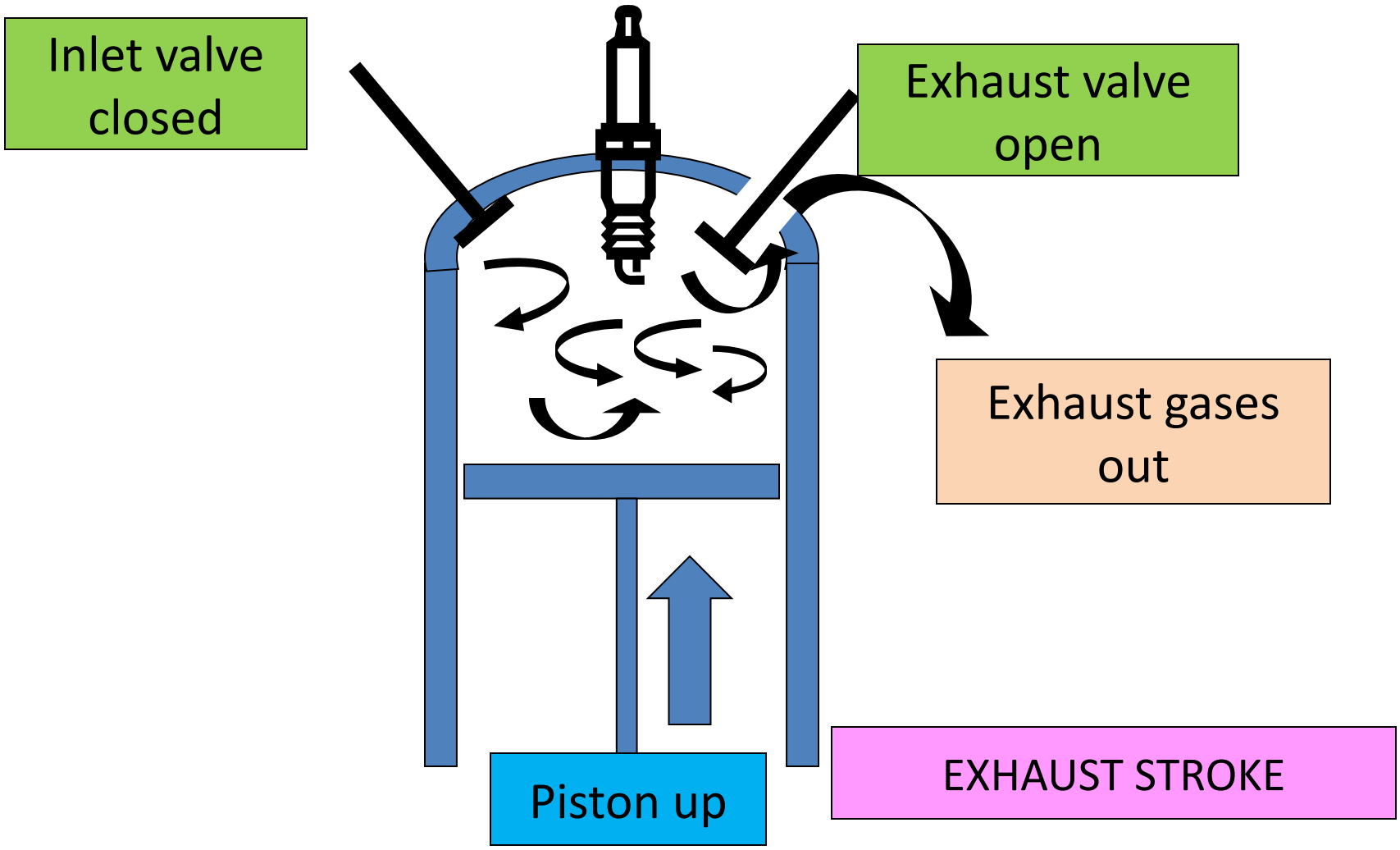
Inlet valve closed



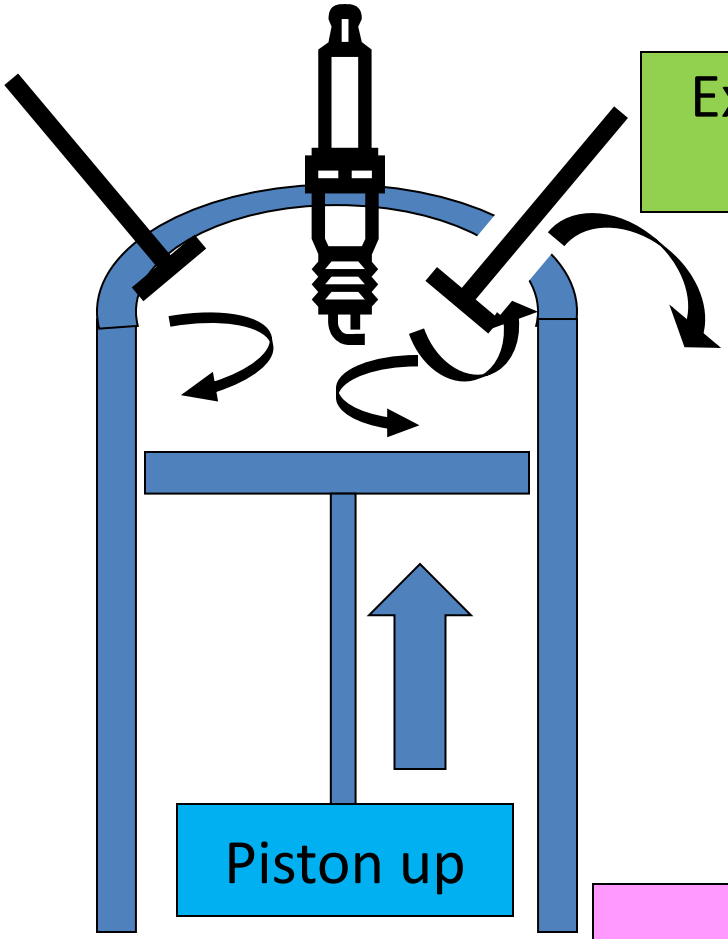
Exhaust valve open

EXHAUST STROKE

The four-stroke engine

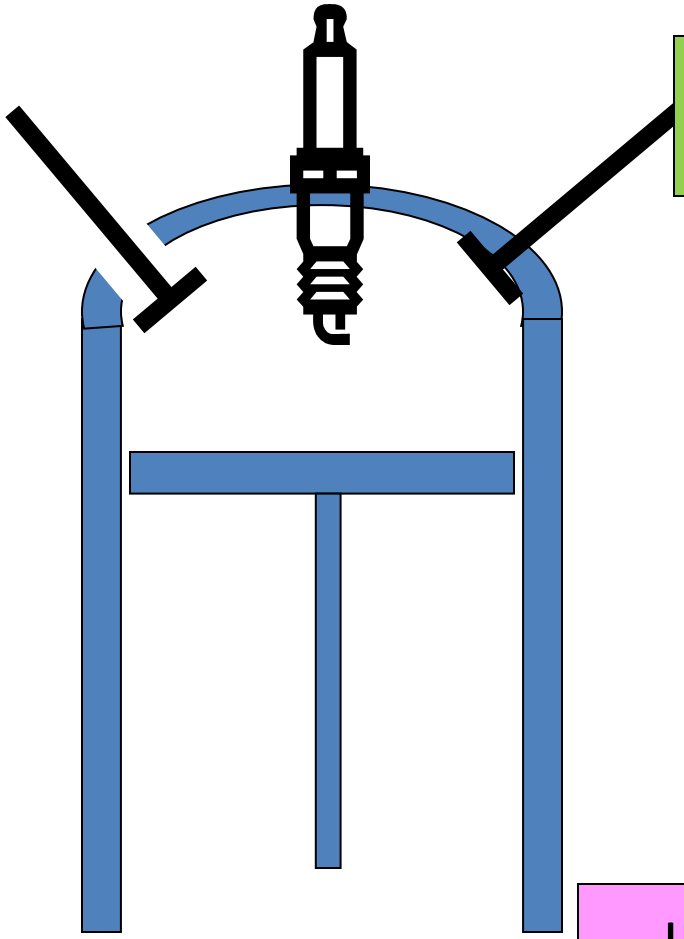


The four-stroke engine



The four-stroke engine

Inlet valve opens

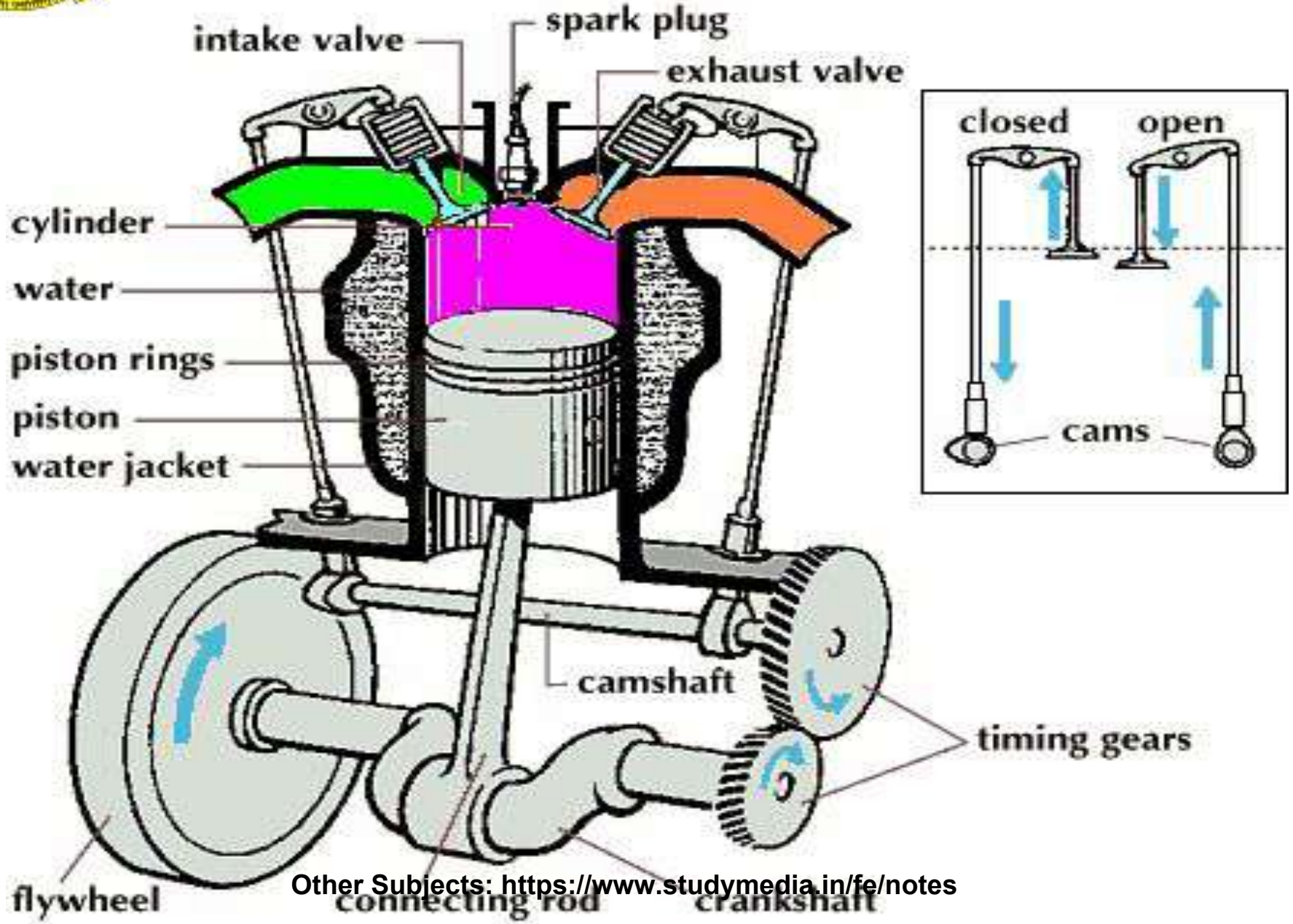


Exhaust valve closed

INDUCTION STROKE

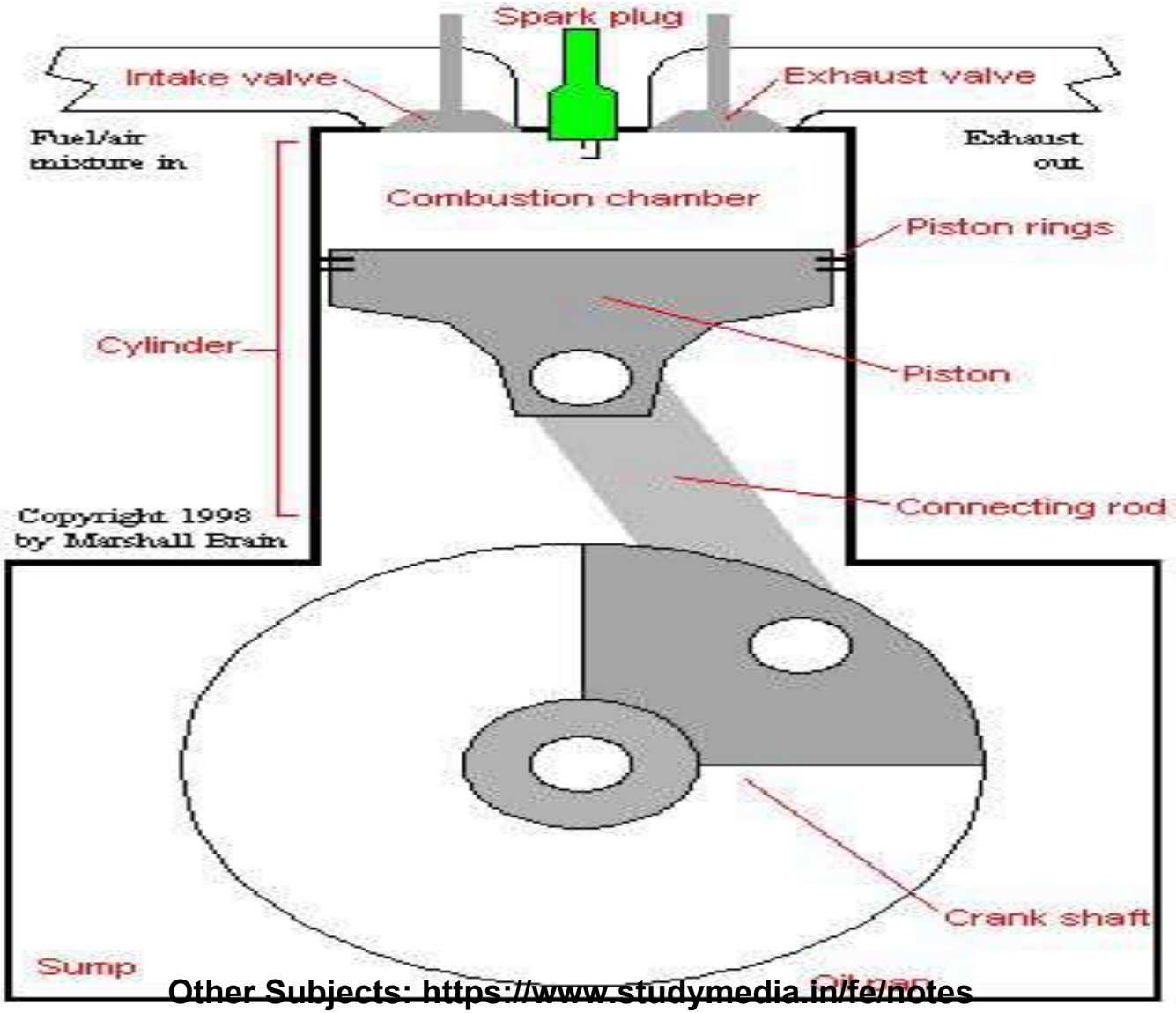
And so the cycle continues!!

WORKING PARTS OF AN ENGINE

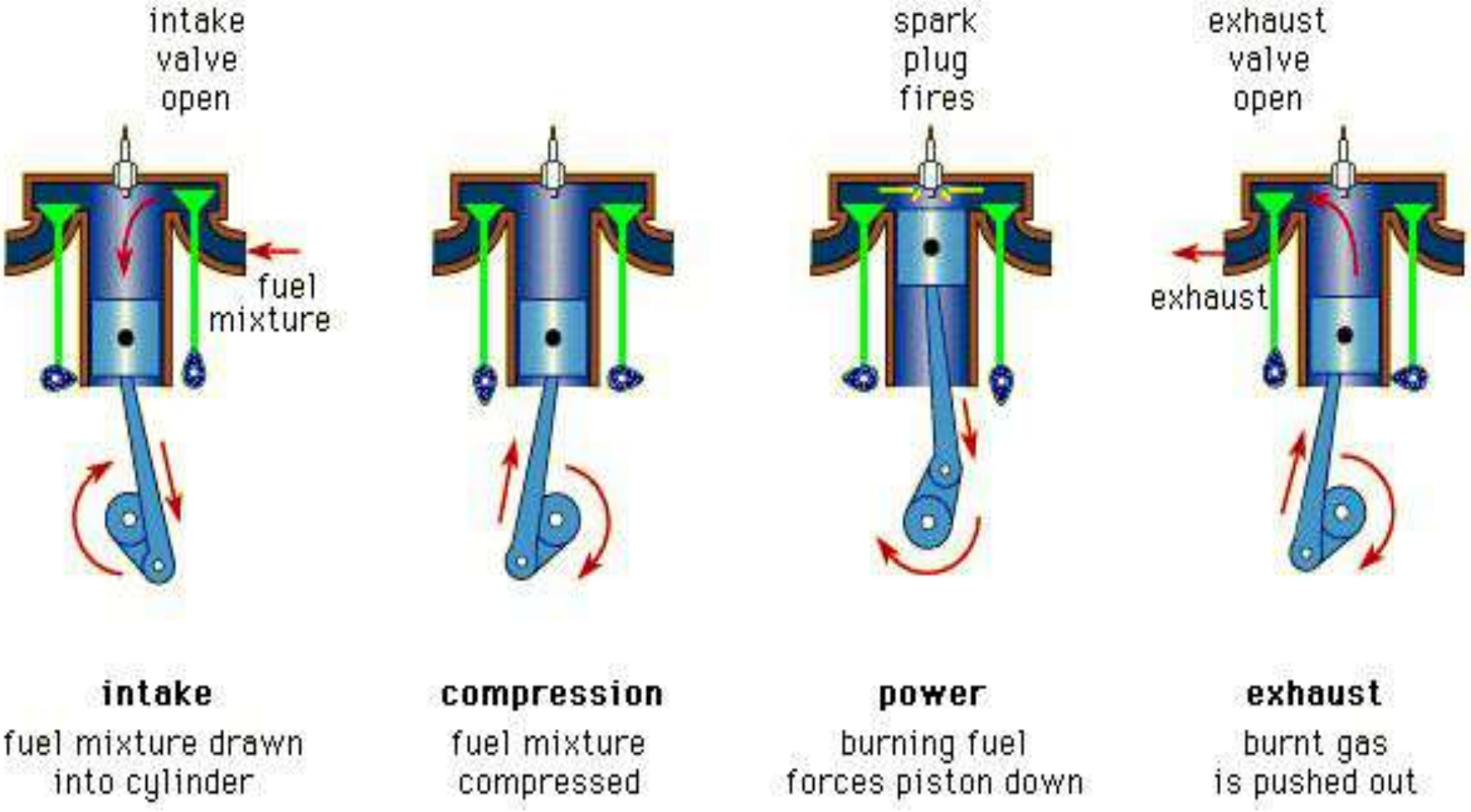


Internal Combustion Engines

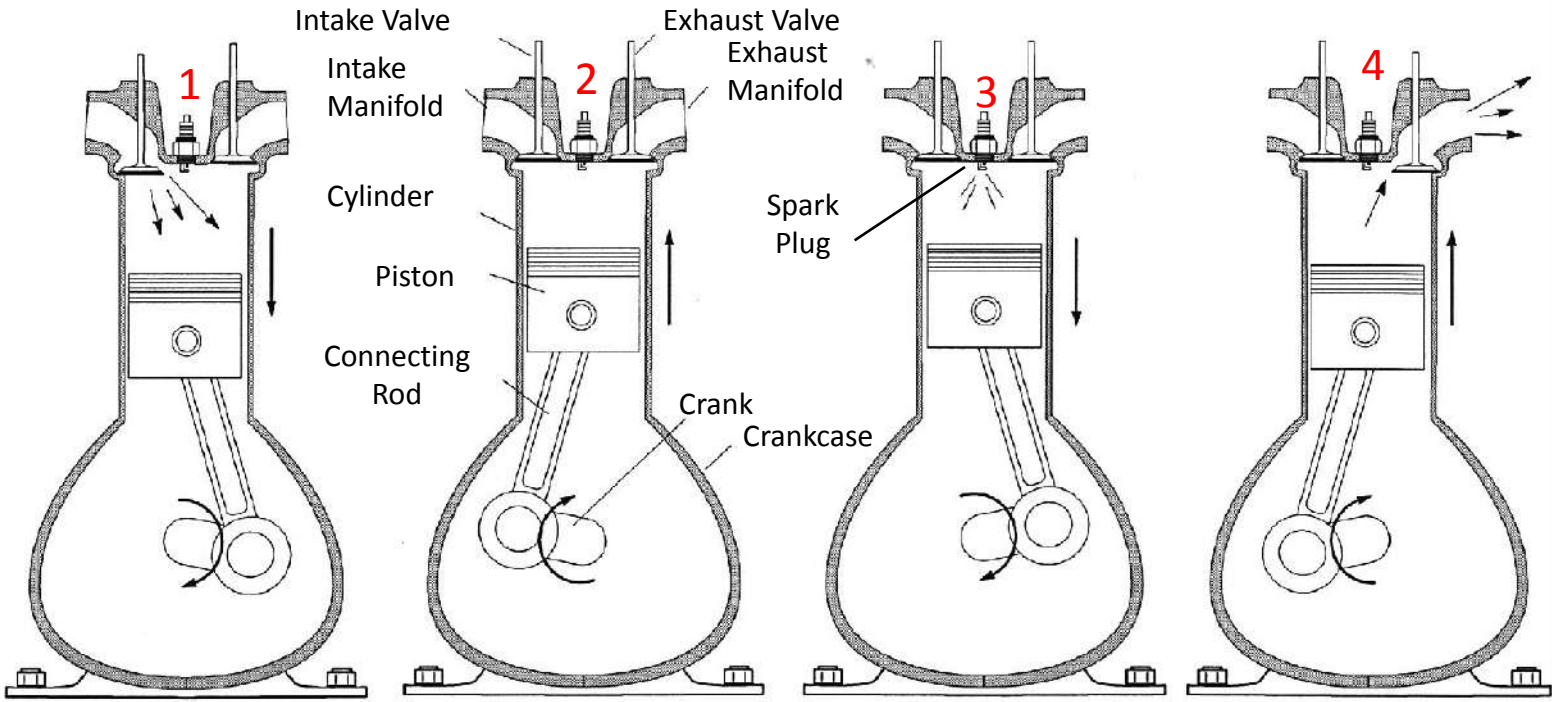
Parts of an Engine



Working of Four Stroke S.I engines or Petrol engine



Working of Four Stroke S.I engines or Petrol engine



Intake Stroke

Intake valve opens, admitting fuel and air. Exhaust valve closed for most of stroke

Compression Stroke

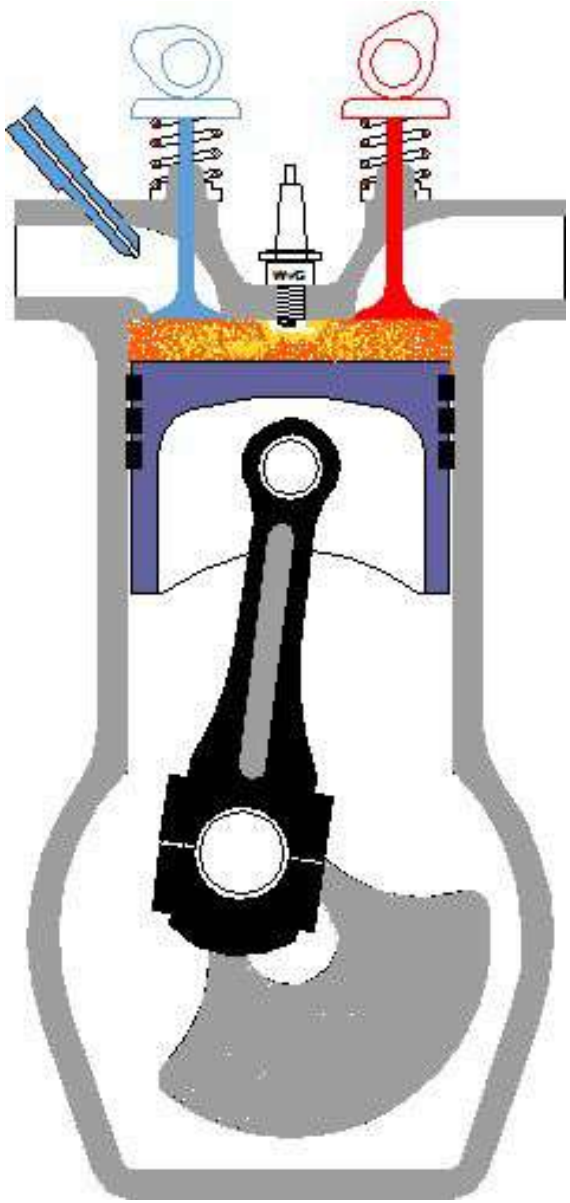
Both valves closed, Fuel/air mixture is compressed by rising piston. Spark ignites mixture near end of stroke.

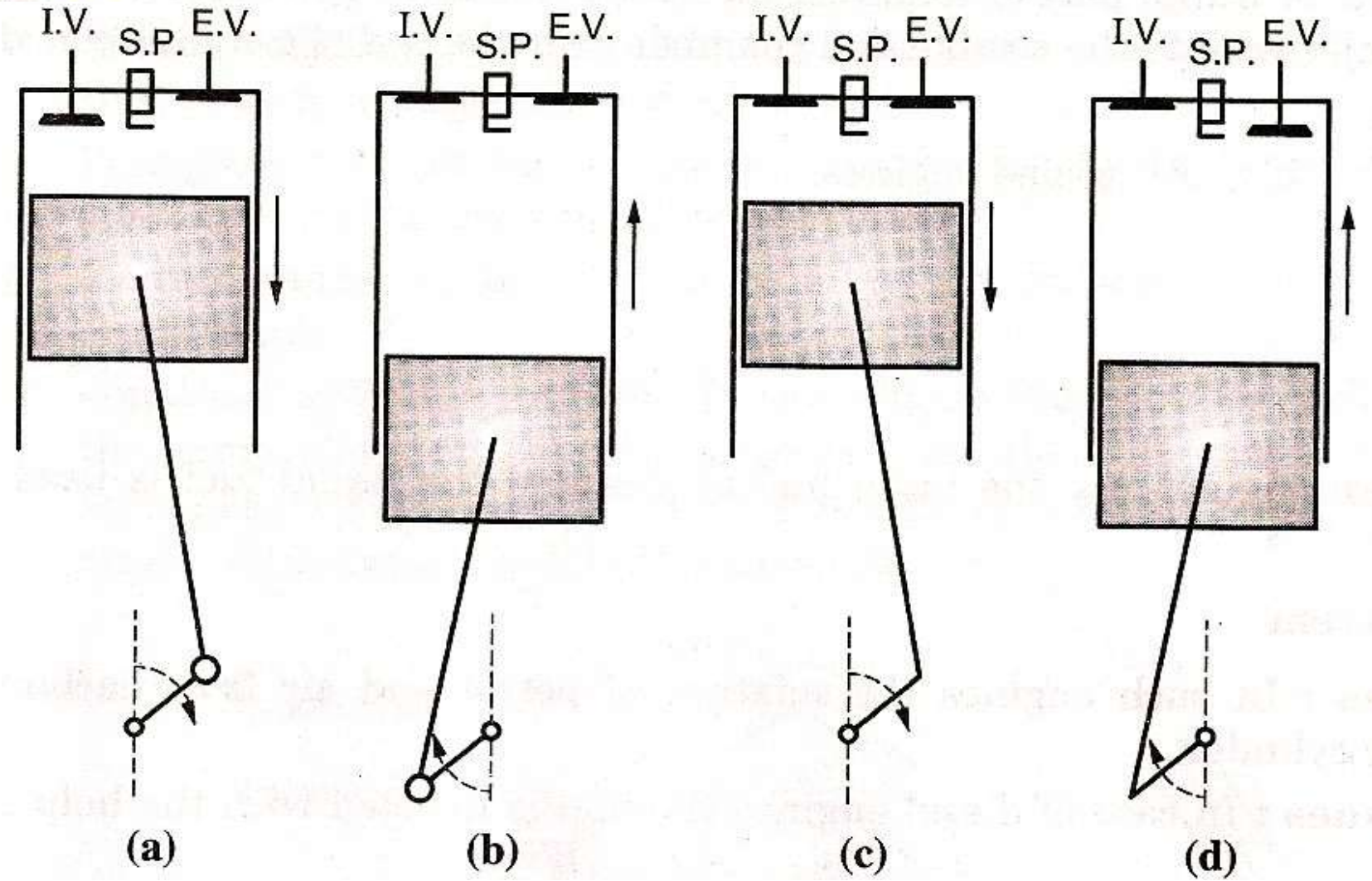
Power Stroke

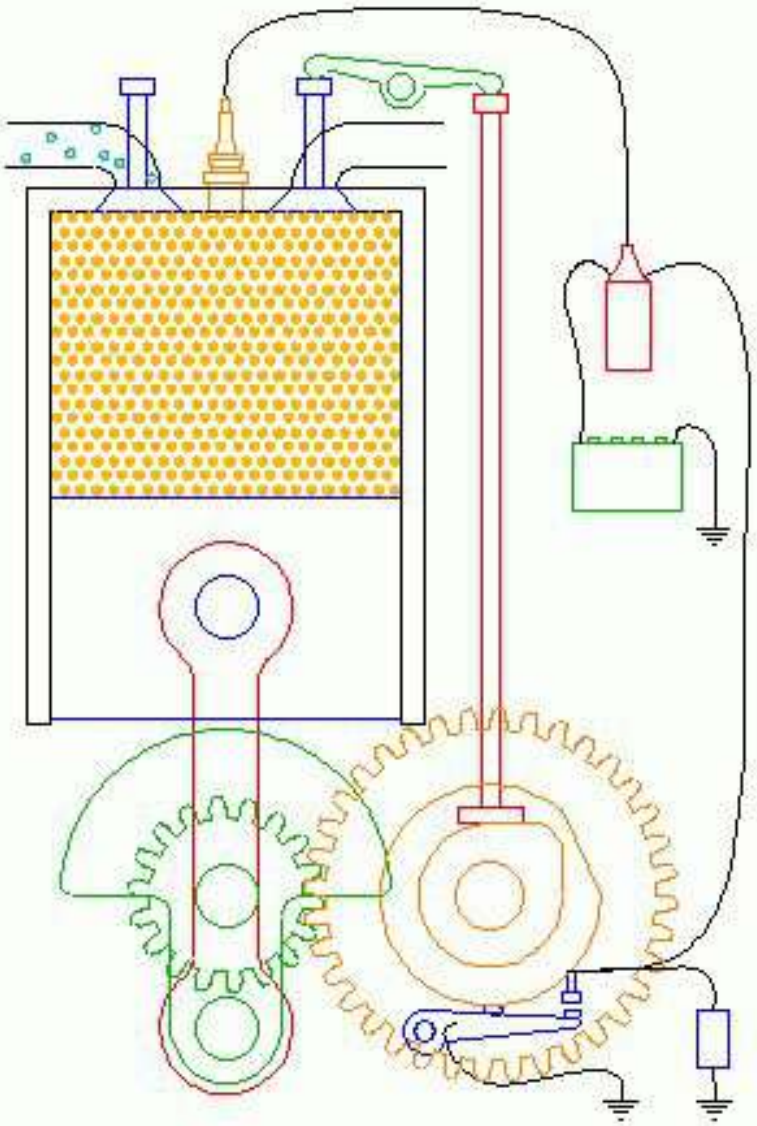
Fuel-air mixture burns, increasing temp and pressure, expansion of combustion gases drives piston down. Both valves closed, exhaust valve opens near end of stroke

Exhaust Stroke

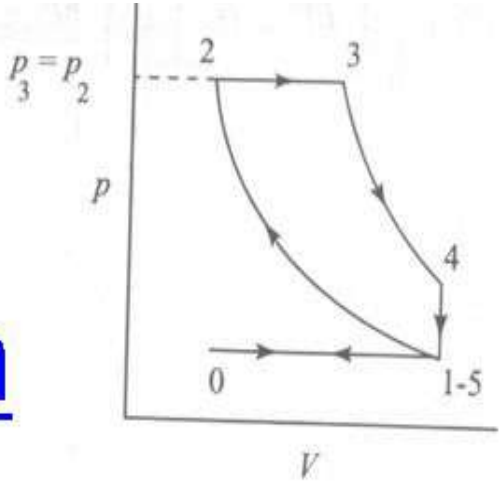
Exhaust valve open, exhaust products are displaced from cylinder. Intake valve opens near end of stroke.

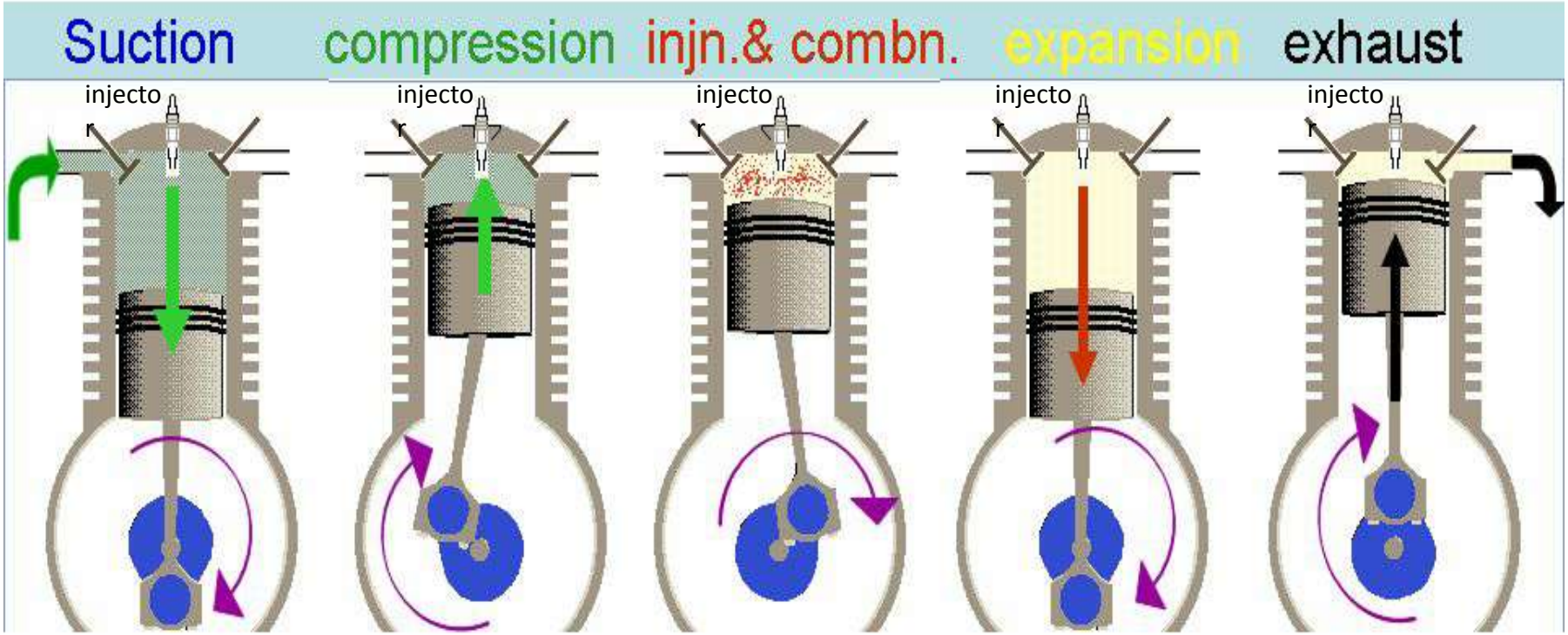




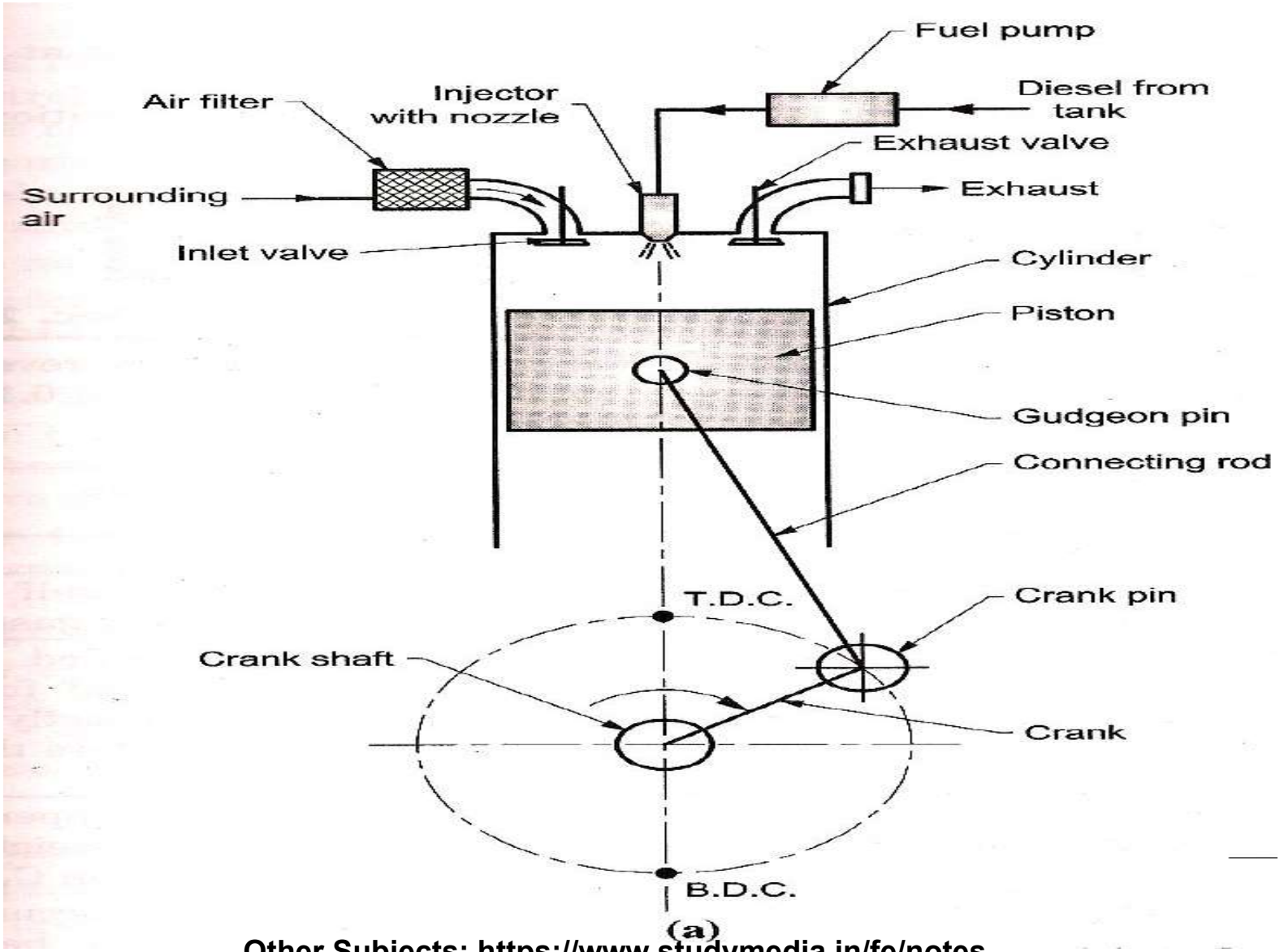


4-stroke Cycle CI Engine Principle of Operation

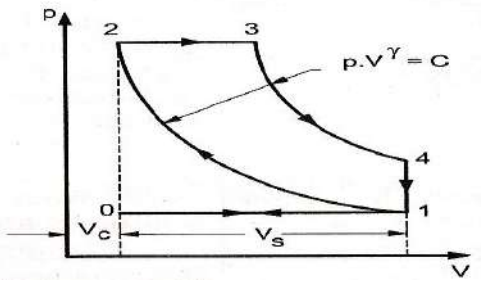


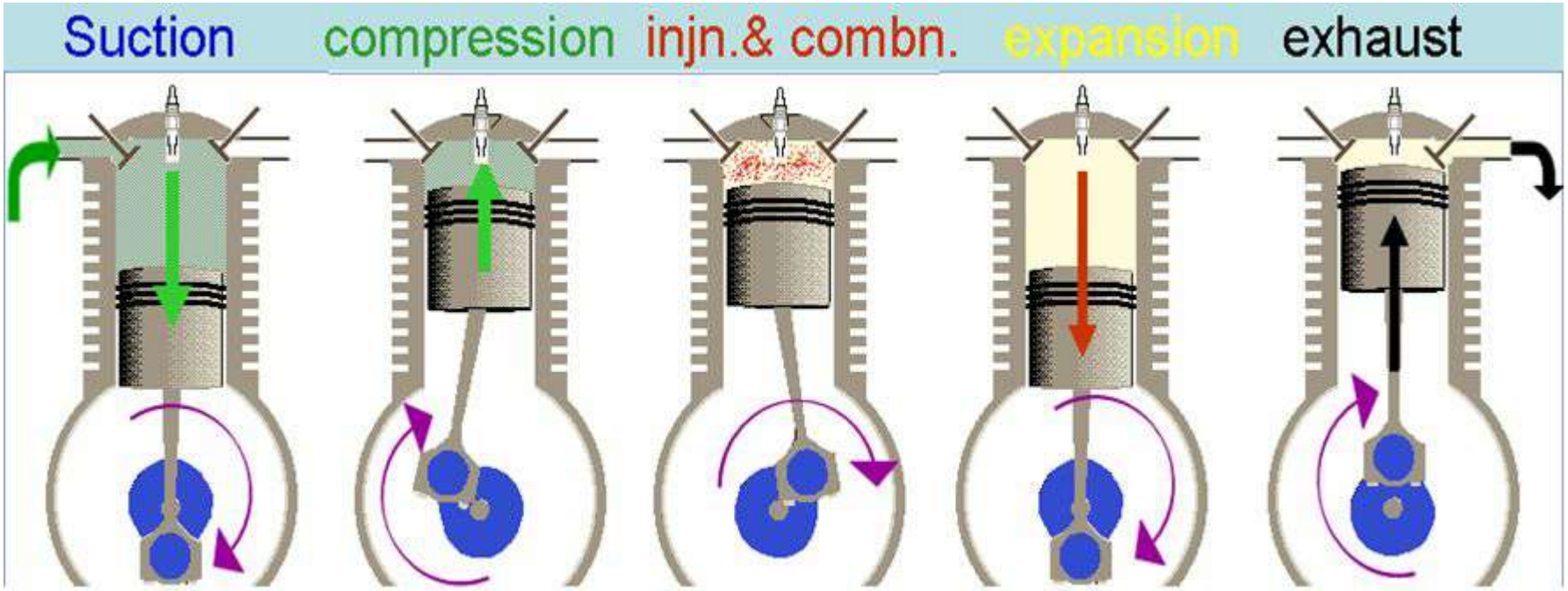


Working of Four Stroke C.I engines or Diesel engine



Working of Four Stroke C.I engines or Diesel engine





Intake Stroke
Intake valve opens, admitting air. Exhaust valve is closed

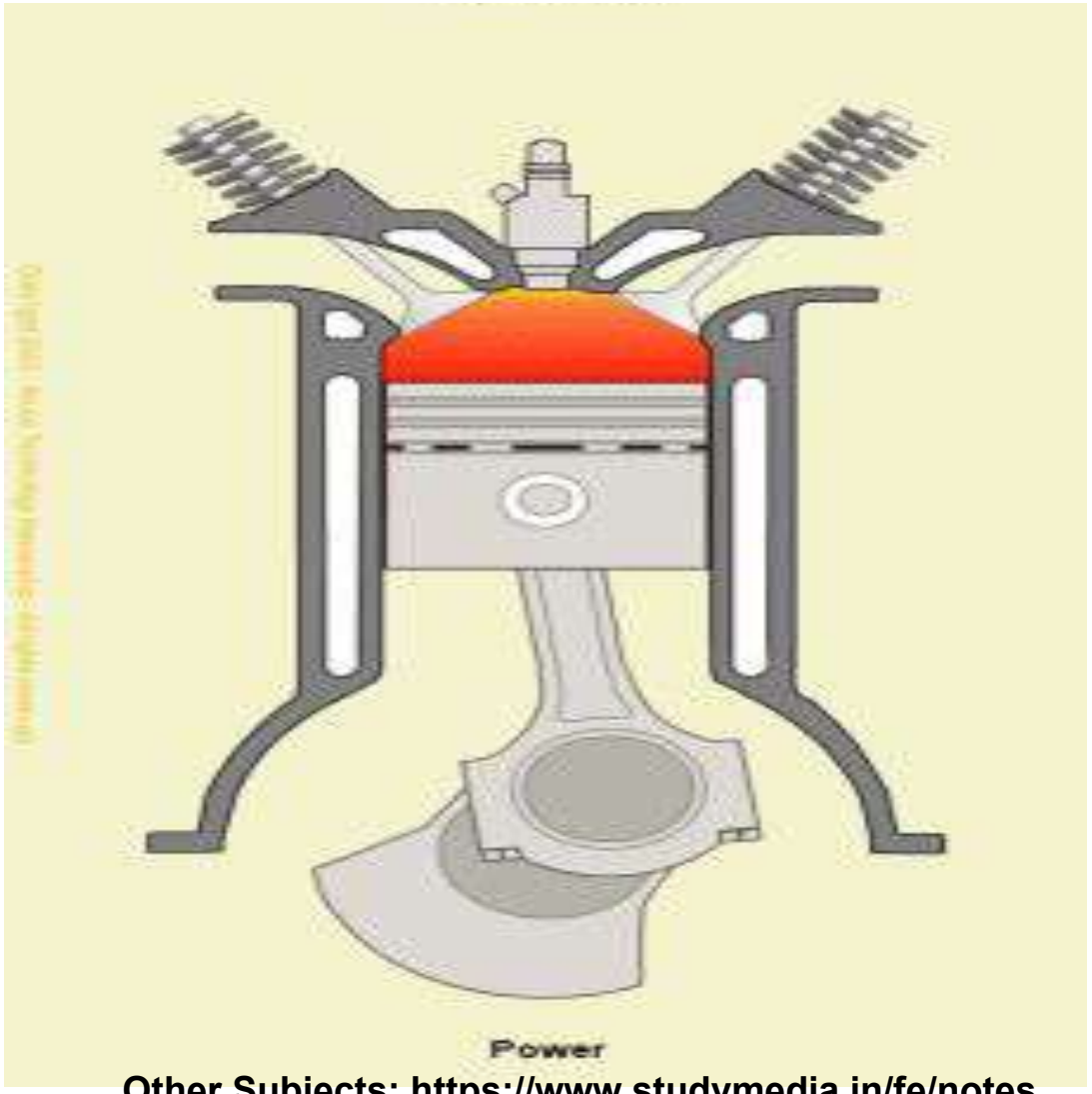
Compression Stroke
Both valves closed, Air is compressed by rising piston.

Injection and combustion
Fuel is injected, due to high temperature of air, fuel is ignited

Power Stroke
Fuel-air mixture burns, increasing temp and pressure, expansion of combustion gases drives piston down. Both valves closed, exhaust valve opens near end of stroke

Exhaust Stroke
Exhaust valve open, exhaust products are displaced from cylinder. Intake valve opens near end of stroke.

Working of four stroke Diesel engine



S.no	Parameter	SI Engine	CI Engine
1.	**Definition**	It is an engine in which the spark is used to burn the fuel.	It is and engine in which heat of compressed air is used to burn the fuel.
2.	**Fuel used**	Petrol is used as fuel.	Diesel is used as fuel.
3.	**Operating cycle**	It operates on Otto cycle.	It operates on Diesel cycle.
4.	**Compression ratio**	Low compression ratio.	High compression ratio.
5.	**Thermal efficiency**	High thermal efficiency.	Less thermal efficiency.
6.	**Method of ignition**	Spark plug is used to produce spark for the ignition.	Heat of compressed air is used for the ignition.
7.	**Engine Speed**	High speed engines.	Low speed engines.
8.	**Pressure generated**	Low pressure is generated after combustion.	High pressure is generated after combustion.
9.	**Constant parameter during cycle**	Constant volume cycle.	Constant pressure cycle.
10.	**Intake**	Air + fuel.	Only air.
	Weight of engine	Si engine has less weight.	CI engine are heavier.
12.	**Noise production**	It produces less noise.	It produces more noise.
13.	**Production of hydrocarbon**	Less Hydrocarbon is produced.	More hydrocarbon is produced.
14.	**Starting**	Starting of SI engine is easy.	Starting of CI engine is difficult.
15.	**Maintenance cost**	Low	High
16.	**Vibration problem**	Less	Very High
17.	**Cost of engine**	Less cost	High cost
18.	**Volume to power ratio**	Less	High
19.	**Fuel supply**	Carburetor	Injector
20.	**application**	It is used in light commercial vehicles like motorcycle, cars etc.	It is used in heavy duty vehicles likes bus, trucks, ships etc.

TWO STROKE & FOUR STROKE

- The stroke of an engine is referred to the distance covered by the piston from the top dead center to the bottom dead center.

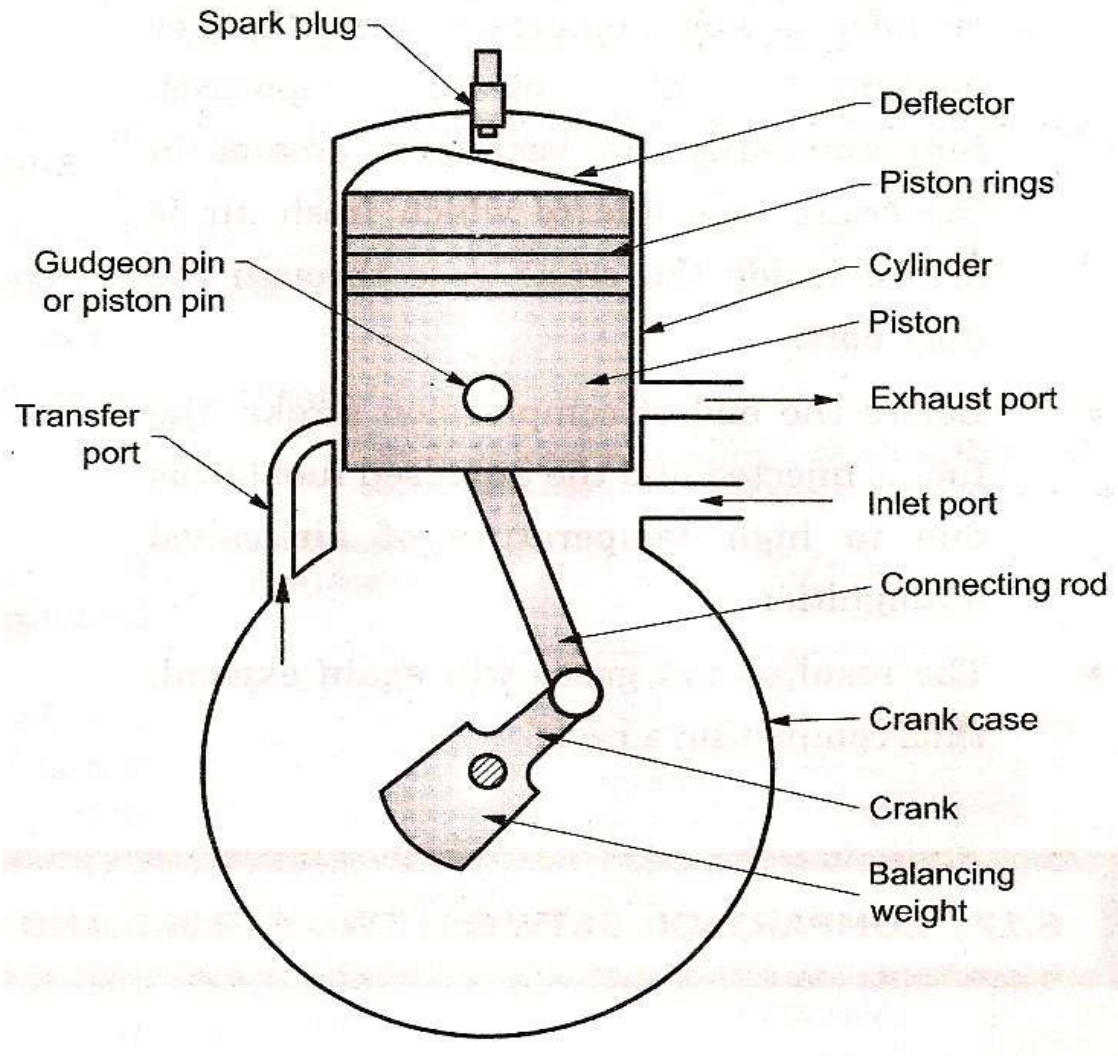
- If the piston moves two times then the engine is called **two stroke** if the piston moves four times then the engine is called **four stroke engine**.

- The crankshaft's rotation is once between two strokes.

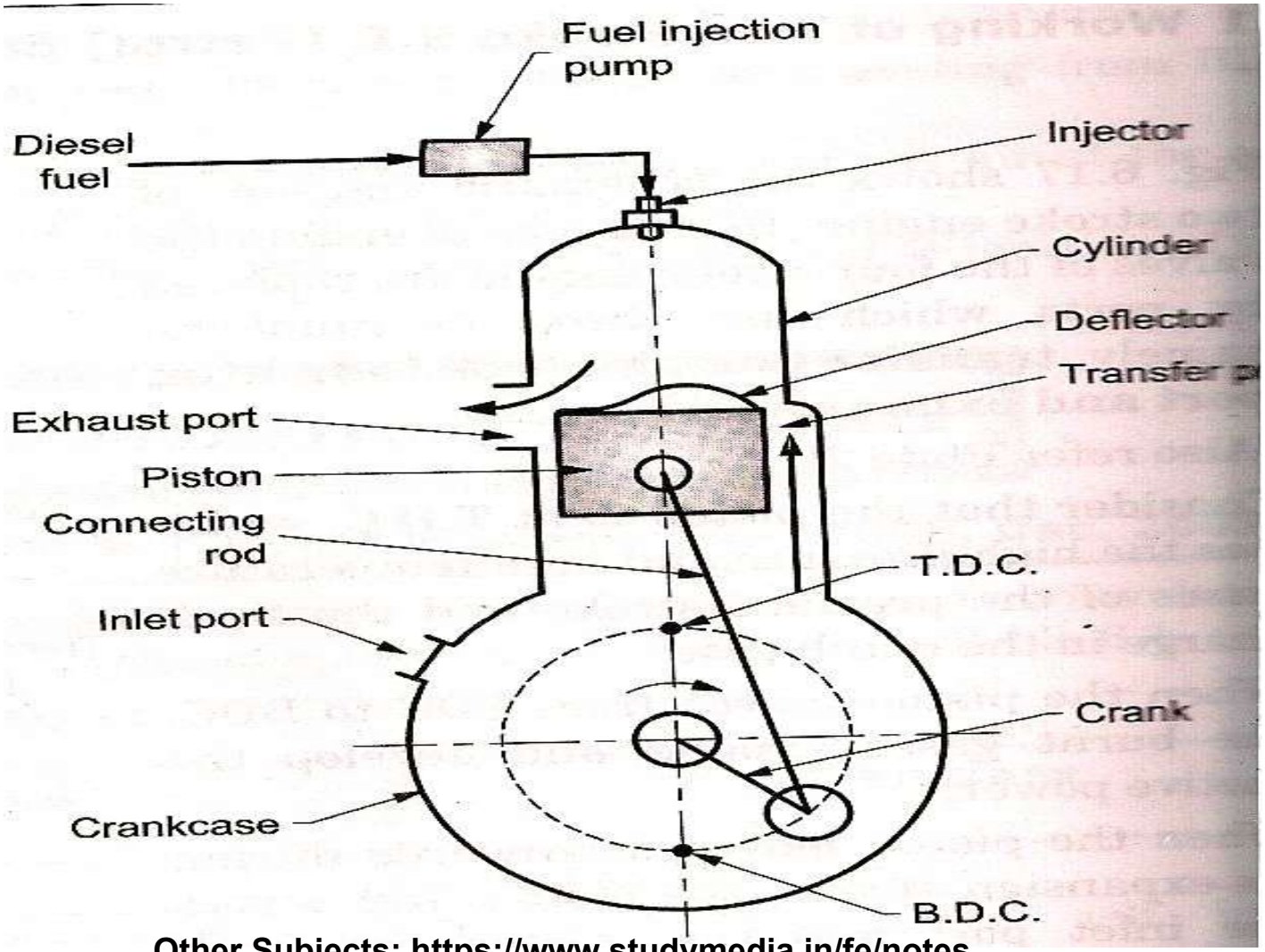
- That means it completes **one complete revolution** in one power stroke in the case of a **two-stroke engine**

- It completes **two revolutions** in one power stroke in case of a **four-stroke engine**.

Two stroke S.I. Engine



Working of two Stroke C.I engines or Diesel engine

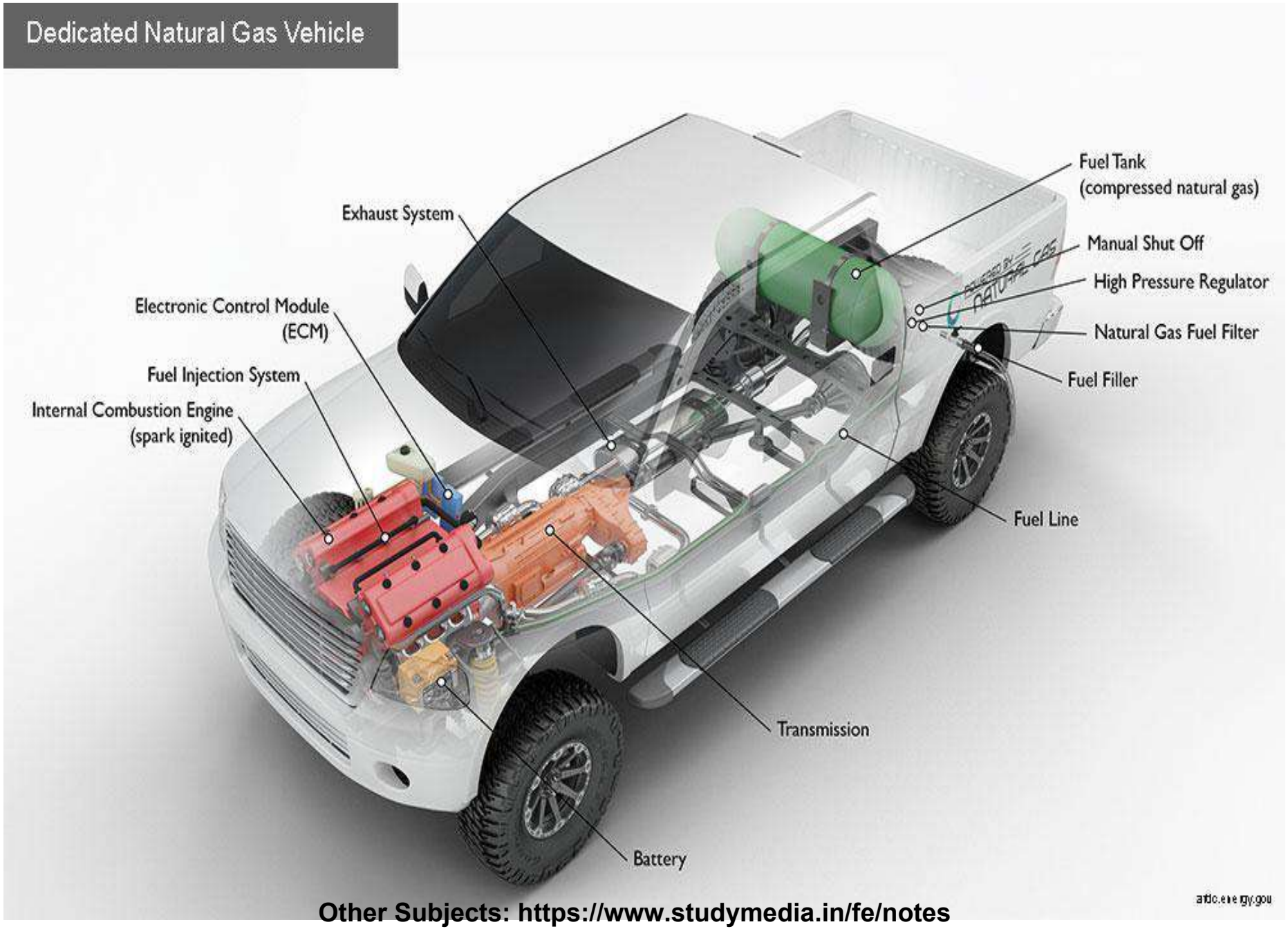


Difference Between Two Stroke and Four Stroke	
Two Stroke	**Four Stroke**
It has one revolution of the crankshaft during one power stroke	It has two revolutions of the crankshaft during one power stroke
It generates high torque	It generates less torque
Its uses ports for fuel's outlet and inlet	It uses valves for outlet and inlet of a fuel
Its engines result in lesser thermal efficiency	Its engines result in higher thermal efficiency
It has a larger ratio in terms of power to weight	It has a lesser ratio in terms of power to weight
It generates more smoke and shows less efficiency	It generates less smoke and shows more efficiency
Requires more lubricating oil as some oil burns with the fuel	Requires less lubricating oil
Due to poor lubrication, more wear and tear occurs	Less wear and tear occurs
Engines are cheaper and are simple for manufacturing	Engines are expensive due to lubrication and valves and are tough to manufacture
Engines are basically lighter and are noisy	Engines are basically heavier because its flywheel is heavy and are less noisy

CNG (Compressed Natural Gas)

- Compressed natural gas (CNG) vehicles work much like gasoline-powered vehicles with spark-ignited internal combustion engines.
- The fuel-air mixture is compressed and ignited by a spark plug.
- The natural gas is stored in a fuel tank, or cylinder, typically at the back of the vehicle.
- A CNG fuel system transfers high-pressure natural gas from the fuel tank to the engine.
- The pressure is then reduced to a level compatible with the engine fuel injection system, through which the fuel is introduced into the intake manifold or combustion chamber

Dedicated Natural Gas Vehicle



Working of CNG Engines

- **Battery:** The battery provides electricity to start the engine and power vehicle electronics/accessories.

- **Electronic control module (ECM):** The ECM controls the fuel mixture, ignition timing, and emissions system; monitors the operation of the vehicle; safeguards the engine from abuse; and detects and troubleshoots problems.

- **Exhaust system:** The exhaust system channels the exhaust gases from the engine out through the tailpipe.

- **Fuel filler:** This is a filler or "nozzle" used to add fuel to the tank.

- **Fuel injection system:** This system introduces fuel into the engine's combustion chambers for ignition.

- **Fuel line:** A metal tube or flexible hose (or a combination of these) transfers fuel from the tank to the engine's fuel injection system

- **Fuel tank (compressed natural gas):** Stores compressed natural gas on board the vehicle until it's needed by the engine.

- **High pressure regulator:** Reduces and regulates the pressure of the fuel exiting the tank, lowering it to an acceptable level required by the engine 's fuel injection system.

- **Internal combustion engine (spark-ignited):** In this configuration, fuel is injected into either the intake manifold or the combustion chamber, where it is combined with air, and the air/fuel mixture is ignited by the spark from a spark plug.

- **Manual shut off:** Allows the vehicle operator or mechanic to manually shut off the fuel supply.

- **Natural gas fuel filter:** Traps dirt and other particles to prevent them from clogging critical fuel system components, such as fuel injectors.

- **Transmission:** The transmission transfers mechanical power from the engine and/or electric traction motor to drive the wheels.