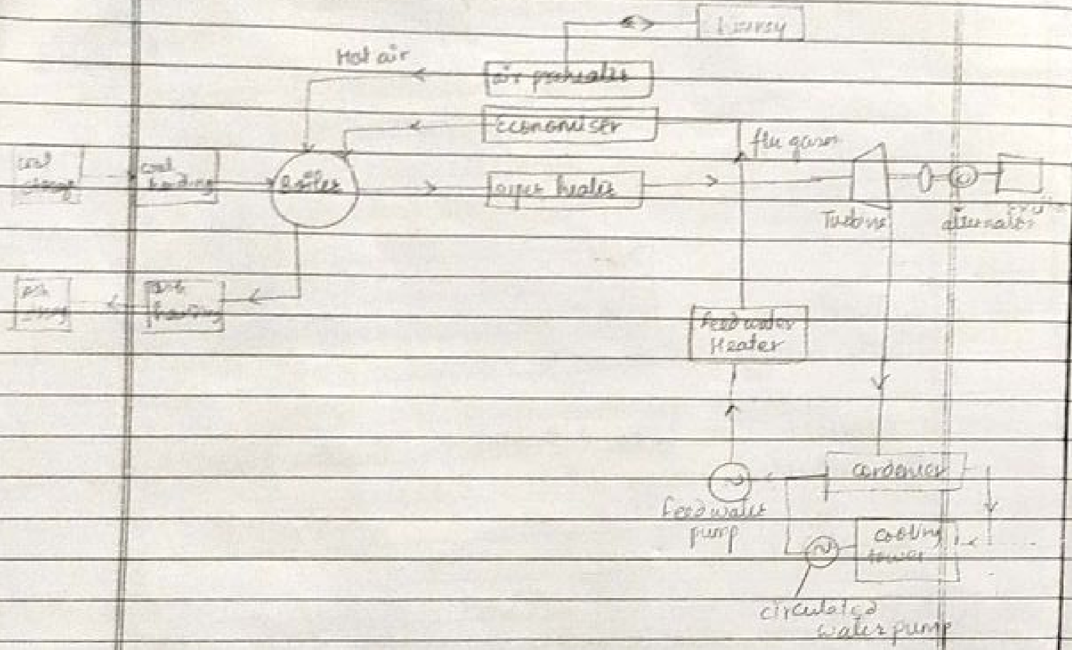
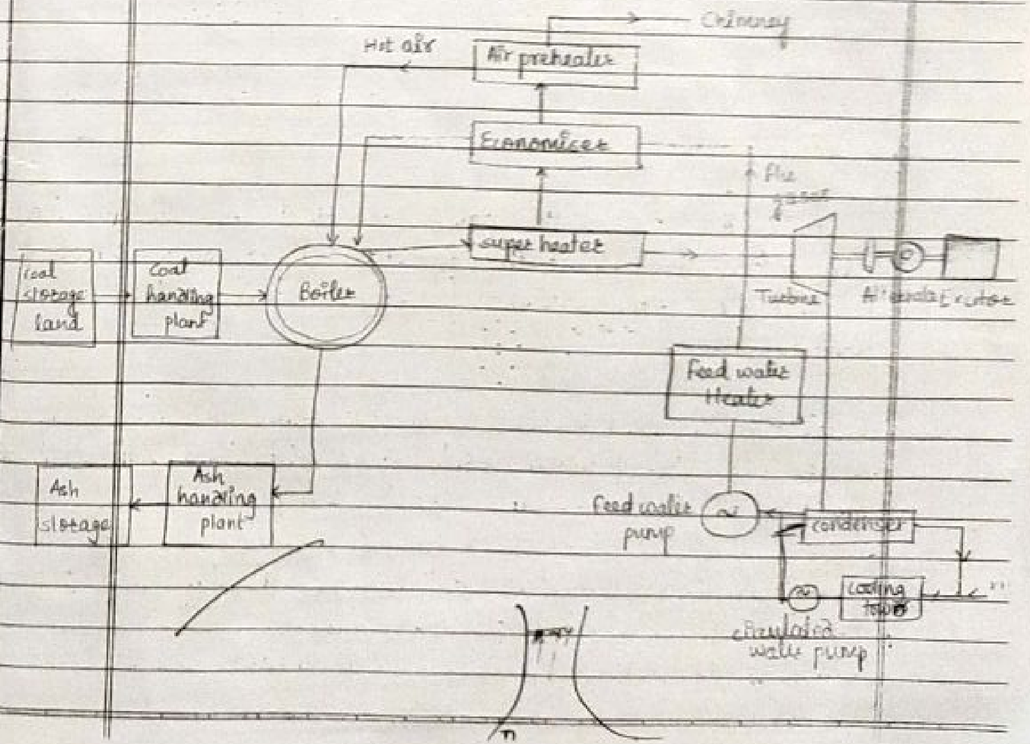


1. Steam Power Plant -:

The steam power plant is important source to produce the electricity. The major portion of electricity demand is fullfilled by the steam power plant. It is also called as thermal power plant.

It is the power plant which is used to generate electricity by the use of steam turbine. The major components of this power plant are boiler, steam turbine, condenser & water feed pump.

Diagram -:



Site selection of steam power plant :-

1. The location of the plant should be at a minimum distance from the load centre (consumer) to avoid transmission losses.
2. Availibility of water is a desirable factor.
3. The water should be preferably free from salt to reduce the cost of water treatment.
4. The soil should be satisfactory for a strong foundation
5. Site should be away from thickly populated areas to reduce the effects of pollution.
6. Adequate transport facility is desirable
7. Space should be available to store coal & ash

Components of power plant :-

1. Coal storage :- It is place where coal is stored which can be utilised when required.

2. Coal Handling :- Here the coal is converted into the pulverised form before feeding to the furnace. A proper system is designed to transport the pulverised coal to the boiler furnace.

3. Boiler :- It converts the water into high pressure steam. It contains the furnace inside or outside the boiler shell. The combustion of coal takes place in the furnace

4. Air-preheater :- It is used to pre-heat the air before entering into the boiler furnace. The pre heating of air helps in the burning of fuel to a greater extent. It takes the heat from the furnace to heat the air atmosphere.

5. Economiser :- As its name indicates it economises the working of the boiler. It heats the feed water to a specified temperature before it enters into the boiler drum. It takes the heat from burnt gases from the furnace to do so.

6. Turbine :- It is the mechanical device which converts the kinetic energy of steam to mechanical energy.

7. Generator :- It is coupled with the turbine rotor and converts the mechanical energy to electric energy

Advantages :-

1. It is more reliable and more efficient
2. Huge capacity.
3. Better efficiency.
4. Large amount of electricity
5. Used for very large capacity power generation
6. It is suitable as a base load power plant.

Disadvantages :-

~~High running charges due to costly price of the diesel.~~

7. It uses cheap, low grade fuel like coal.
8. It is adopted for combined cycle operation.

Disadvantages -

1. It requires huge capital investment and maintainence cost.
2. It is complicated in construction.
3. It requires large space.
4. It causes environmental pollution and damage to ecology.
5. Ash disposal & acid rain through chimney gases is a problem.
6. It requires huge water supply.
7. Its overall efficiency is less as compared to other power plant.
8. It requires more man power for operation.
9. It has a long warm-up boiler.

Applications -

1) Chemical Industry :- Providing heat and electricity to drive diff. processes in the chemical and pharmaceutical industries. steam turbines are integrated in the process of producing power.
2) Waste Plants :- Steam turbine help generate the power needed to harness energy from waste.
3) Oil & Gas :- Used as pump driver on a compressor, steam turbines support dozens of operations in the oil and gas industry.
4) Sugar Mills :- Offering high levels of effeciency and sustainable operations, steam turbines are used to produce green carbon-dioxide energy from bagasse.

Working -:

① In the steam power plant the pulverised coal in fed into the boiler and it is burnt in the furnace.
② The water present in the boiler drum changes to high pressure steam. From the boiler the high pressure steam passed to the super heater where it is again heated upto its dryness.
③ This super heated steam strikes the turbine blades with a high speed and the turbine starts rotating at high speed.
④ A generator is attached to the rotor of the turbine and as the turbine rotates it also rotates with the speed of the turbine.
⑤ The generator converts the mechanical energy of the turbine into electrical energy. After striking on the turbine steam leaves the turbine and enters into the condenser.
⑥ The steam gets condensed with the help of cold water from the cooling tower.
⑦ The condensed water with the feed water enters into economiser. In the economiser the feed water gets heated up before entering into the boiler. This heating of water increases the efficiency of the boiler.
⑧ The exhaust gases from the furnace pass through the super heater, economiser and air pre-heater. The heat of this exhaust gases is utilised in the heating of steam in the super heater, feed water in the economiser and air in the air pre-heater. After burning of the coal into the furnace it is transported to ash handling plant & finally to ash storage.

Two Stroke Engine :-

Working of 2 stroke Engine :-

① In small engines, the exhaust and inlet ports are made in the cylinder block When a piston comes down from the Top Dead Center (TDC) to the Bottom Dead Center (BDC) during a power stroke, it opens the exhaust gases are allowed to escape.

② As the piston travels down a little more, it also uncovers the inlet port which is usually located opposite the exhaust port. Due to uncovering of the inlet port by the piston, a fresh charge comes into the cylinder.

Hence, suction and exhaust are completed in one stroke

③ When a piston travels up from the BDC to TDC, it covers both, the inlet and exhaust ports and so the charges gets trapped and compressed. This is the commencement of a compression stroke. When a piston reaches the TDC, a spark is triggered from the spark plug and the charge (mixture of air and fuel) ignites. The charge gets expanded due to rapid combustion caused by explosion and it causes the piston to move down with force. This is known as power stroke

④ At the same time, when the piston is at TDC, the piston stirt uncovers the port in the cylinder block from where a fresh charge goes into the crank case due to a partial vaccum created by the crank shaft and its weight.

⑤ Thereafter when piston starts moving down in power stroke, the charge which has come in to the crank case is pressed by crank weights to the inlet port side, ready to be taken to the cylinder. In this way, a whole cycle is completed.

Four Stroke Engine :

Working of 4 stroke Engine :

A four-cycle engine works with 4 basic steps to a successful rotation of the crankshaft : the intake, compression, power and exhaust stroke. Each corresponds to one full stroke of the piston; therefore the complete cycle requires two revolutions of the crankshaft to complete.

① Intake :-

During the intake stroke, the piston moves downward drawing a fresh charge of vaporized fuel/air mixture. The illustrated engine features a poppet intake valve which is drawn open by the vaccum produced by the intake stroke. Some early engines worked this way; however, most modern engines incorporate an extra cam/lifter arrangement as seen on the exhaust valve. The exhaust valve is held shut by a spring (

② Compression :-

As the piston rises, the poppet valve is forced shut by the increased cylinder pressure. Flywheel momentum drives the piston upward, compressing the fuel/air mixture.

③ Power :-

At the top of the compression stroke, the spark plug fires, igniting the compressed fuel. As the fuel burns it expands, driving the piston downward.

④ Exhaust :-

At the bottom of power stroke, the exhaust valve is opened by the cam/lifter mechanism. The upward stroke of the piston drives the exhausted fuel out of the cylinder.

Difference between SI and CI Engine :-

SI Engine	CI Engine
1. Constant volume cycle	1. Constant pressure cycle.
2. Petrol is fuel, which has a high self ignition temperature	2. Diesel is used, has a low self ignition temperature.
3. These are high speed engines.	3. Low speed engines
4. Low thermal efficiency.	4. High thermal efficiency.
5. Knocking takes place at the end of the combustion.	5. Knocking takes place at the beginning of combustion.
6. Homogenous mixture of fuel & hence a high pressure is formed.	6. Heterogenous mixture, hence low pressure is generated.
7. Fuel used in these engines is expensive.	7. Cheaper fuels are used in these engines.
8. Initial cost is less ↓	8. Initial cost is high ↑
9. Engines are more compact & light	9. Heavier and strong engine due to higher pressure involved.

Two Stroke Engine	Four Stroke Engine
1. 1 cycle complete in every revdn of crank shaft.	1. 1 cycle complete in every 2 revolution of crank shaft.
2. Less moving parts	2. More moving parts.
3. Less maintance.	3. More maintenence.
4. Less in weight and more compact because produce twice power compared to 4 stroke engine.	4. Heavy in weight & required more space, because of one power stroke for two revolutions.
5. Less expensive.	5. More expensive.
6. It has no valve but port inlet, outlet & transfer port	6. It has valve and valve mechanism.. inlet and exhaust valve.
7. Less pollution.	7. Produce more pollution.
8. Short engine life.	8. Long engine life.
9. Design is simple.	9. Design is complex.
10. Generally air cooled system used.	10. Generally water cooled system used.
11. Less cost.	11. More cost
12. Less output due to mixing of fresh charge with hot burnt gases.	12. More output due to full fresh intake and full burnt gases exhaust.
13. More fuel consumption and fresh charge mixed with exhaust gases.	13. Less fuel consumption & complete burning of fuel.
14. Simple lubrication system.	14. Complicated lubrication system.
15. More noise created	15. Less noise created.
16. Less thermal efficiency	16. More thermal efficiency.
17. Consume more lubricant oil.	17. It consumes less lubricant oil.
18. More wear and tear of moving parts.	18. Less wear and tear of moving parts.
19. Lighter flywheel required	19. Heavy flywheel required

Spark Ignition Engine :-

A spark-ignition engine (SI engine) is an internal combustion engine, generally petrol engine, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug.

This is an contrast to compression-ignition engines, typically diesel engines where the heat generated from compression together with the injection of fuel is enough to initiate the combustion process without needing any external spark.

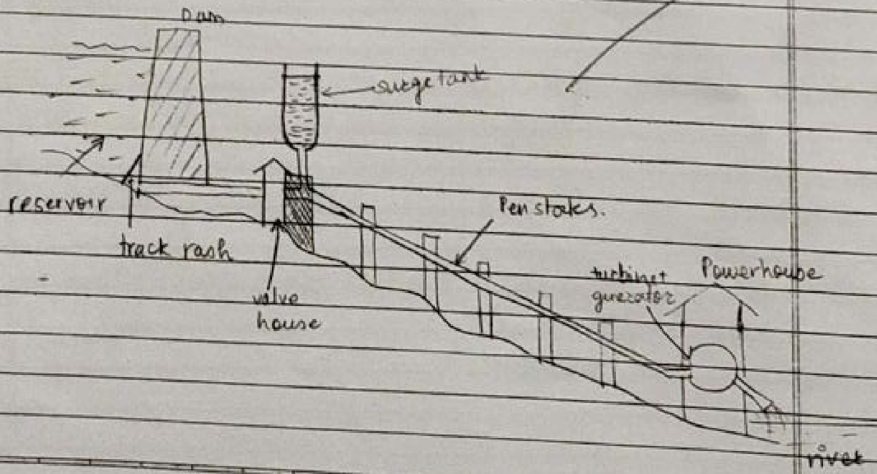
- Working of SI Engine -

The working of

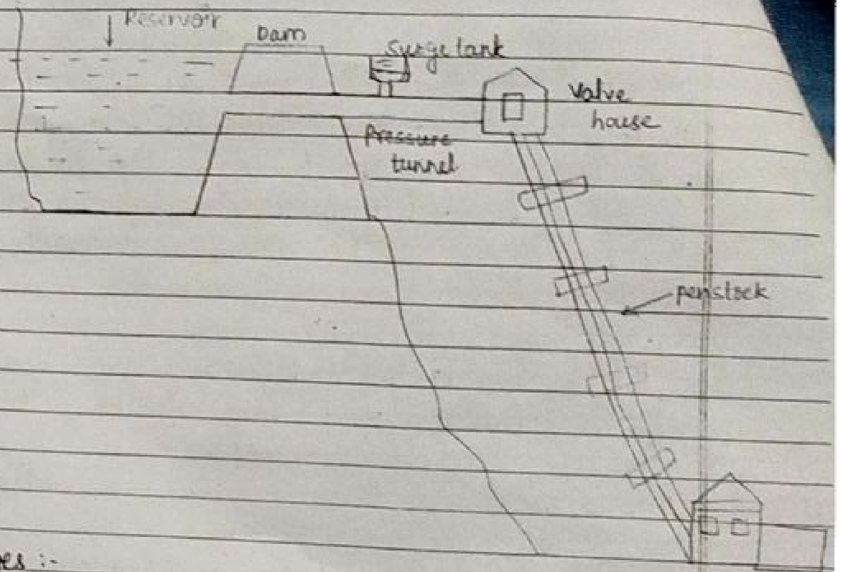
Compression Ignition Engine :
(CI Engine):

CI Engine is (also known as diesel engine) named after Rudolf Diesel, is an internal combustion engine in which ignition of the fuel, which is injected into the combustion chamber, is caused by the elevated temp of the air in the cylinder due to the mechanical compression (adiabatic compression).

Diesel Engine work by compressing only the air. This increases the air temperature inside the cylinder to such a high degree that atomised diesel fuel injected into the combustion chamber ignites spontaneously. This contrasts with spark-ignition engines such as a petrol engine (gasoline engine) or gas engine (using a gaseous fuel as opposed to petrol), which use a spark plug to ignite an air-fuel mixture. In diesel engines, glow plugs (combustion chamber pre-warmers) may be used to aid starting in cold weather, or when the engine uses a lower compression-ratio, or both. The original diesel engine operates on the "constant pressure" cycle of gradual combustion and produces no audible knock



Hydroelectric Power Plant :-



★ Advantages :-

1) Large power output can be tapped out, high efficiency.
2) Turbine units are suitable for low, medium or high power output ranges.
3) Pollution free, working, running cost is also low
4) side project like irrigation, flood control also can be commissioned.

★ Disadvantages :-

1) Mainly dependent upon rainfall & water storage.
2) Large initial cost towards dam construction, land acquisition, Rehabilitation of the subjected community
3) Suitable site for dam construction of water reservoir are not available to plenty.

Solar thermal power plant :-

It uses the sun's rays to produce electricity. Photovoltic plants and solar thermal system are the most commonly used solar technologies today. A solar thermal plant generate heat & electricity by concentrating the sun's energy that in turn builds steam that helps to feed a turbine & generator to produce electricity.

Types :- 1) Parabolic throughs
2) solar power tower
3) Solar pond

Advantages :-

1) No fuel cost & doesn't require any fuel.
2) Predictable, 24 hr power
3) No pollution & global warming effects.
4) Uses existing industrial base
5) Easy to store & dispatch.

Disadvantages :-

1) Solar energy is not available at night or during cloudy day.
2) High cost.
3) Limited location & size.
4) Weather dependent.

Working :-

1) Concentrating solar power plants produce electric power by converting the sun's energy into high temp. heat using various mirror configuration. The heat is chanelled thr a conventional generator.
2) The plant consists 2 parts.
one that collect solar energy & converts into heat &
another that converts heat energy into electricity.
3) Solar power plant consists of concentrating system, turbin generator & cooling circuit.

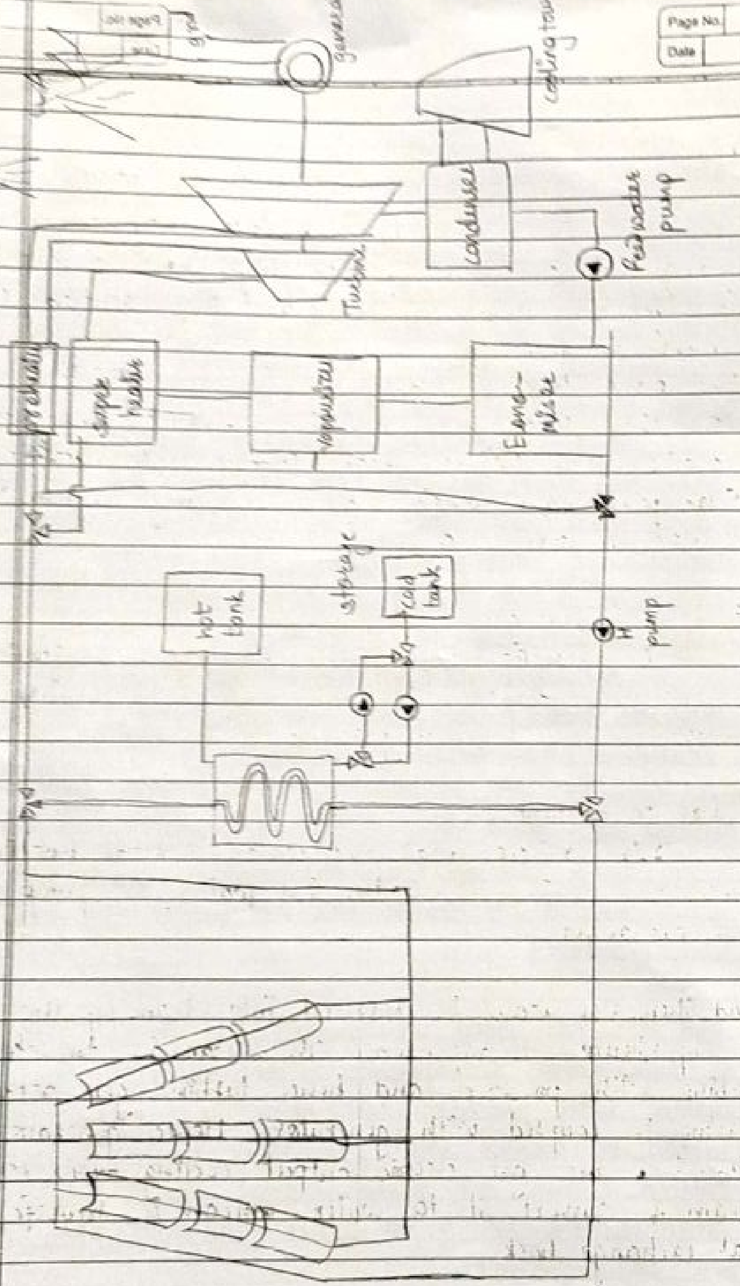
(i) Parabolic troughs :-

A parabolic trough collector has a long parabolic shape reflector that focuses the sun's rays on a receiver ~~pipe~~ located at the focus of parabola.

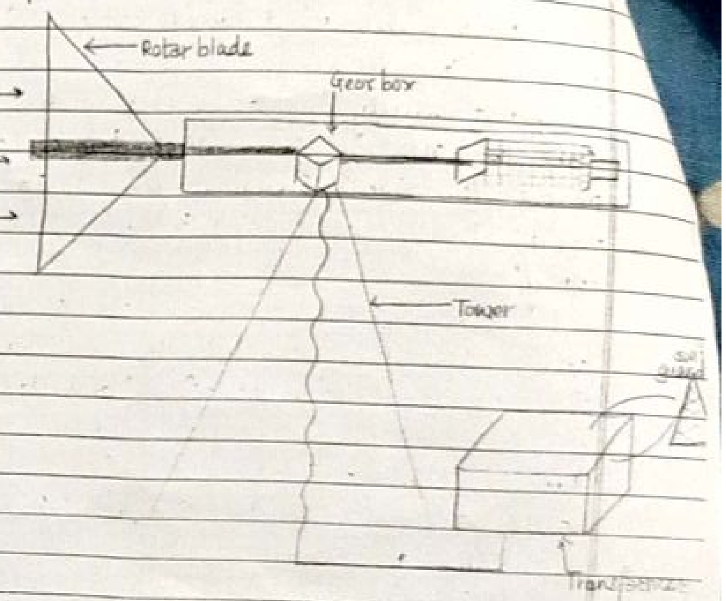
(ii) Hot water tank :-

Solar collector heat the water is made hot in hot water tank & it circulate the hot water thr pump toward heat exchanger.

And then hot water is converted into steam by the working of superheater & vapourizer. The steam is transferred to turbine with pressure and hence turbine gets rotated. Turbine is coupled with generator. Hence generator also rotated & we get electric output. Cooling tower condenses steam & convert it to water which is transferred to heat exchanger back.



* Wind power plant :-



Wind turbine extracts energy from moving air by slowing the wind down & transfering this energy into spinni shaft. which usually turns a generator to produce electricity. The power in the wind thats available for harvest depends on both the wind speed and area that swept by turbine blades.

Working :-

Blades of the wind turbine works ~~on~~ on airfoil of diff cross-sections all along the length. When fluid (air) moves over the airfoil, it generate a lift force thus making the blade to rotate at its axis. This generator is also connected to rotor shaft starts rotating & produce electricity

Now, we all know that rotating blades can get as electricity, but wind speed keeps on changes with time so we get a fluctuation in power. To overcome this, threshould velocity is decided at which turbine will start ~~w~~ rotating below that breaks are used to prevent the blades from rotating and for high wind velocity breaks are applied to prevent turbine from damage.

Motar & sensors are used to rotates the blads about their axis so that they can adjust according to the varying direction of wind and to extract maximum power out of wind. Blades are also rotated to stop the turbine from rotating means they are oriented in a such a way that no lift will be generated even with the blowing wind.

In a wind power plant turbines are required to be interconnected to get the best out of them. They are connected to each other by a medium voltage power collection system usually around 35 5 kV along with a communication network that helps in communication.

* Advantages :-
1) Wind energy is an inexhaustible source of energy is virtually a limitless source.
2) Energy is generated without polluting environment.
3) Land around wind turbines can be used for other uses.
4) In remote areas, wind turbines can be used as great resource to generate energy.

* Disadvantages :-
1) Wind energy requires expensive storage during peat production time.
2) It is reliable energy source as winds are uncertain and unpredictable.
3) There is visual and asthatic input on region.
4) Require large open area for installation.
5) Noise pollution problem is usually associated with wind mi

* Nuclear Power Plant :-

In this, heat energy is generator by nuclear reaction called nuclear fission. This is done by nuclear reactor and other parts are similar to thermal power plant.

Parts in nuclear power plant :-
1. Nuclear reactor.
2. Heat exchanger.
3. Steam turbine.
4. Alternator.
5. Condensor.

1. Nuclear reactor :-

1) Special apparatus used to perform nuclear fission. It is process when a heavy nucleus is splitted into 2 or more small nuclei. During which huge amount of energy is released.
2) A nuclear reactor consists of fuel rods, control rods and moderator. A fuel rod contains small round pallets.
3) Control rods of cadmium which absorb neutron. They are inserted into reactor & can be moved in or out to control the reaction.

4) The moderator can be graphite rods or the coolent itself. Moderator slows down the neutron before they bombard on fuel rods.

2 Types – ① Pressurised water reactor
② Boiling water reactor

2) Heat exchanger :-
In the heat exchanger the primary coolant transfers heat to secondary coolent. Thus water from secondary loop is converted into steam. The primary steam & secondary steam are closed loop & they are never allowed to mix up with each other. Thus heat exchanger helps in keeping secondary system free from radioactive stuff. Heat exchanger is absent in boiling water reactors.

3) Steam turbine:-
Generated steam is passed thr a steam turbine which runs due to pressure of steam. As the steam is passed thr turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator thr a rotating shaft.

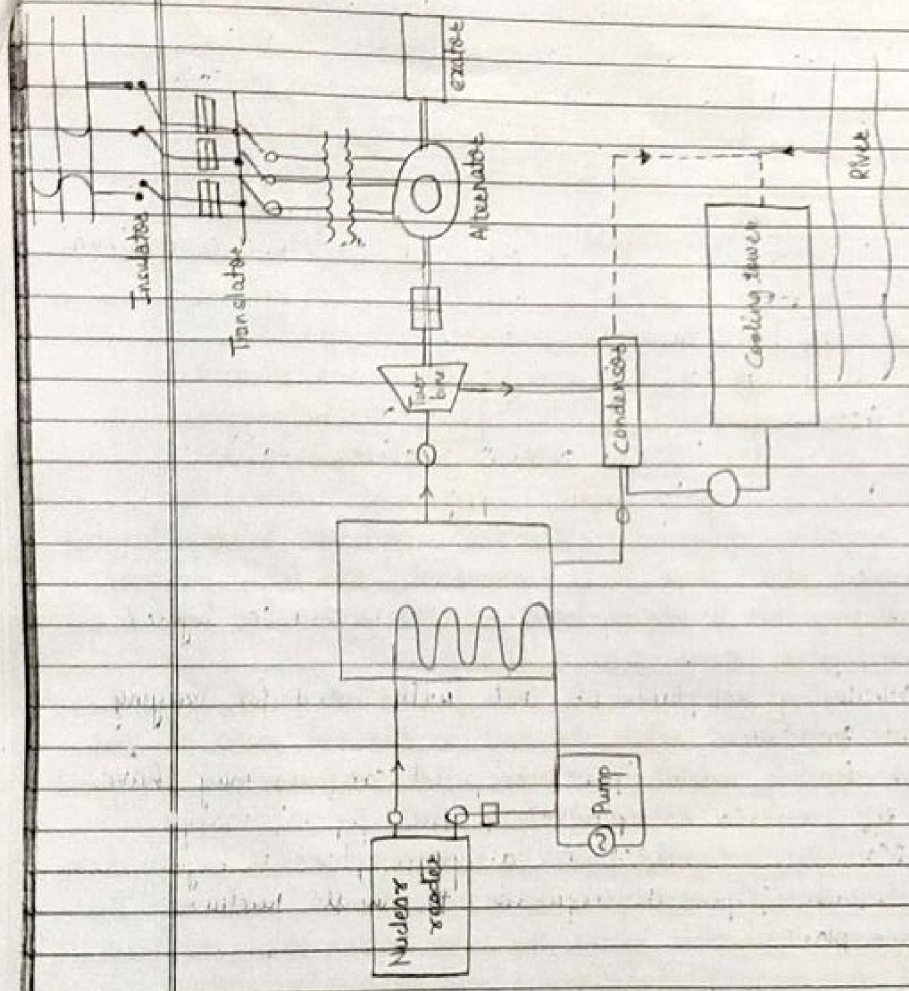
4) Alternator :-
The steam turbine rotates the shaft thus, generating electrical energy. Electrical output of alternator is delivered to step up transformer to transfer it over distances.

5) Condenser :-
The steam coming out of turbine, after it has done its w... it then converted back into water in a condenser. The steam is cooled by ~~by~~ passing it thr a third cold water loop.

- Advantages:-
1) Space needed is less as compared to other conventional power plant.
2) Consume less amount of fuel.
3) Fuel transportation cost is low.
4) There is increased realibility of operation
5) Not affected by unfavourable weather conditions.
6) No need of large water supply.

- Disadvantages :-
1) Initial cost to set up is high a compared to hydro/steam power plant.
2) Nuclear power plants are not well suited for varying load conditions.
3) Radioactive wastes if not disposed carefully may have an effect on health of operators & the populah nearby.
4) Maintainence cost of nuclear power plant is high.
5) Trained people are required to handle nuclear power plant.

Module- 2.



Refrigeration :-

It is the process of extracting heat from an enclosed space or from a substance in order to cool & rejecting the extracted heat to atmosphere.

Heat pump :-

Device to maintain temp of system above atmosphere temp.

COP :-

It is defined as cooling effect produced to work input

$$COP = \frac{\text{desired o/P}}{\text{Required I/P}}$$

$COP_{(R)}$ that is for refrigerator

$$COP_{(R)} = \frac{\text{desired cooling effect}}{\text{work supplied}}$$

$$= \frac{Q_L}{Q_H - Q_L}$$

$COP_{(HP)}$ = Heat pump

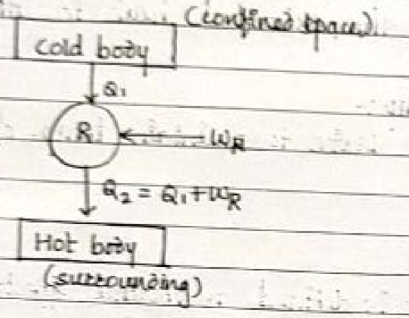
$$= \frac{\text{desired heating effect}}{\text{work supplied}}$$

$$COP_{(HP)} = \frac{Q_H}{Q_H - Q_L}$$

$$\boxed{COP_{(HP)} = COP_{(R)} + 1}$$

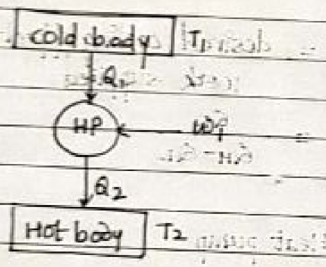
* **Refrigerator:**

To transfer heat energy from low temp. region to high temp. region



* **Heat pump:**

To transfer heat energy from low temp. region to high temp. region with some external work supplied



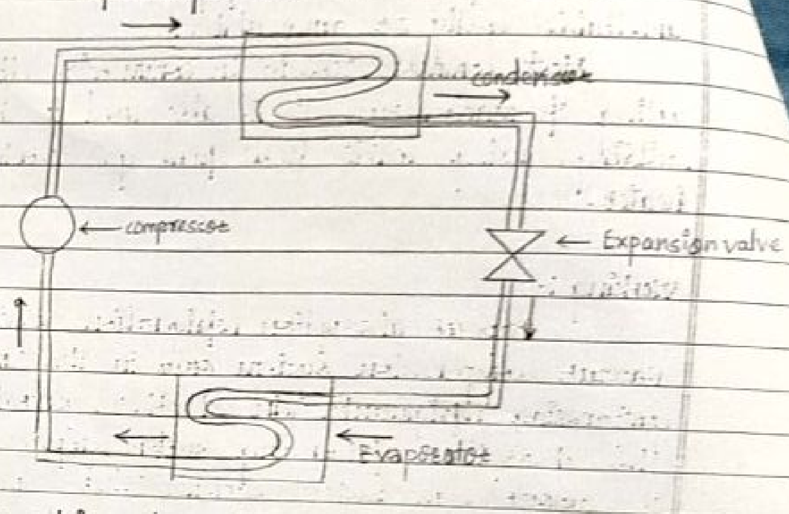
* **Vapour compression refrigeration system:**

Vapour compression refrigeration used for domestic & commercial refrigerator.

working:

The vapour - compression refrigeration system uses a circulating fluid refrigerant as medium, which absorbs heat from the space to be cooled and rejects that heat to atmosphere.

components: compressor, condensor, expansion valve, ~~ep~~ evaporator



Circulating refrigerant enters the compressor in a saturated vapour state. Here it is compressed to a high pressure resulting into a higher temp of the refrigerant and is in superheated vapour state.

The hot vapour is then passed thr tubes of condense Here refrigerant rejects its heat to the cool water or cool air flowing outside the tubes. This condenses the refrigerant & it comes in saturated liquid state.

The saturated liquid is then rotated thr an expansion valve where it undergoes a in reduction in pressure. The pressure reduction lowers the temp colder than the temp of the enclosed space to be refrigerates.

The cold mixture is then passed thr coil of the evaporator. The evaporator coil absorb the heat & cool air subsequently from the substance kept in the enclosed space. The refrigerant leaving evaporator is in saturated vapour state which is passed back to compression.

Scanned by CamScanner

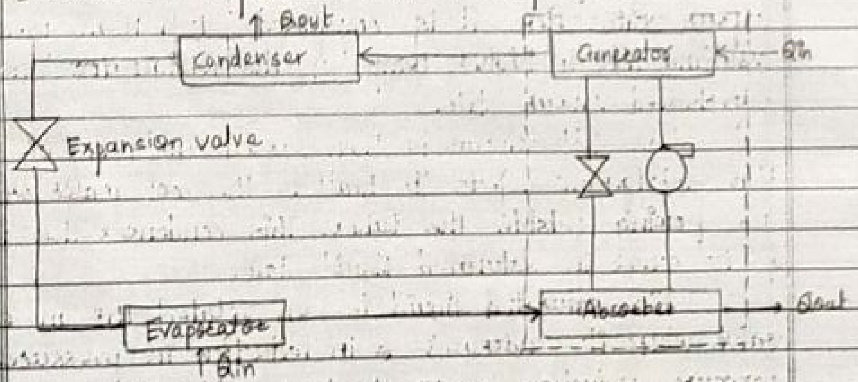
* ~~Vapour absorption refrigeration system~~ :-

These refrigerators are popular where electricity is unreliable costly or unavailable.

Most common use is in commercial climate control & cooling of machinery. It is also used to air condition buildings using waste heat from gas turbine or water heater.

working :-

Vapour absorption refrigeration system differs from vapour compression system only in the method of compressing refrigerant. An absorber, generator & pump in the absorption refrigerating system, replace the compressor of vapour compression system. Other components are condenser, expansion valve & evaporator.



Ammonia vapour is produced in the generator at high pressure by external heating source. The water vapour carried with ammonia is removed & only dehydrated ammonia gas enters the condensor. High pressure ammonia vapour is condensed in condenser. The cooled ~~expansion val~~

~~ammonia vapour is condensed in condenser.~~ solution is passed thr valve & pressure & temp of refrigerant is reduced below the temp to be maintained in evaporator. The low temp refrigerant enter the evaporator. It absorbs required heat from evaporator & leaves evaporator as saturated vapour.

Slightly superheated, low-pressure ammonia vapour is absorbed by weak ammonia solⁿ entering the absorber becomes a strong solⁿ after absorbing ammonia vapour which is pumped to generator thr heat exchanger. The pump increases the pressure of the strong solⁿ of ammonia to the generator pressure. It may be noted that the strong solⁿ of ammonia coming from absorber in the heat exchanger is at lower temp than the weak ammonia solⁿ coming from generator. Thus strong ammonia solⁿ absorbs heat in exchanger from weak ammonia solⁿ. The ammonia solⁿ entering generator becomes weak as NH_3 vapour comes out of it. The weak high temp solⁿ entering generator is passed to heat exchanger into the absorber thr valve. Thus pressure of liq ammonia is reduced to absorber pressure by valve.

Diff. betn

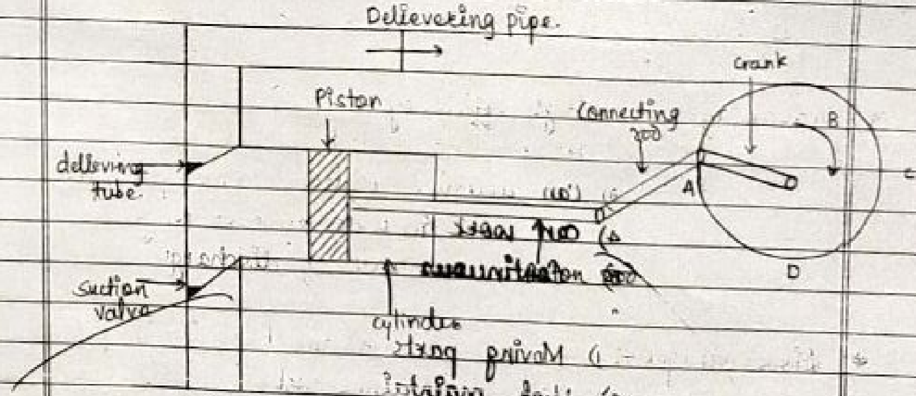
Vapour compression	Vapour absorption
1) uses mechanical work as high grade energy.	1) Uses heat that is low grade energy. Hence may be worked on exhaust system from internal combustion energy, gas turbine etc.
2. Moving part are in the compressor hence subjected to more wear & tear rate	2. Moving parts are in the pump which is small element of system hence operation is smooth.
3. COP decreases with decrease in evaporator pressure	3. COP is not affected
4. Performance is adversly affected at partial load	4. Performance is not affected
5. Automatic operation for controlling the capacity is difficult	5. Automatic operation for controlling the capacity is easy.
6 Electric power is needed to drive the system.	6. Waste of exhaust system steam may be used. No need of electric power
7. charging of refrigerant is difficult	7. Charging of refrigerant is easy. (ammonia)

Pumps :-

Hydraulic machine which converts mechanical into hydraulic energy. (Hydraulic energy is in the form of pressure energy)

Pump
- RF Pump
  - Centrifugal pump
  - Axial pump
- Positive displacement pump
  - Reciprocating pump
    - piston/plunger pump
    - diaphragm pump
  - Rotary pump
    - Gear pump
    - Lobe pump
    - Helical screw pump
    - Sliding vane pump

Working of Reciprocating pump . advantages and disadvantages:-



These are positive displacement pumps.
It consists of piston which moves forward & backward inside cylinder with the help of connecting rods & crank. Cylinder is connected to sump thr suction pipes & to delivery tank by delievery pipe.
When the crank moves from A to C the piston moves from left to right and it create vaccum in the cylinder. This vaccum causes suction valve to open and liquid from source is sucked by suction pipe into cylinder. When crank moves from C to A, piston will move towards left and compresses the liquid in the cylinder. Now pressure makes the delivery valve to open & liquid will discharge thr delievery pipe. Then again crank rotates, A to C to create suction & whole process is repeated.

* Application:- Used for-
  1) Oil drilling operations
  2) Pneumatic pressure system
  3) Light oil pumping
  4) Feeding small boilers condensate return.

* Advantages:- 1) High efficiency
  2) No priming needed
  3) Can delivers water at high pressure
  4) Can work in wide pressure range
  5) Continuous rate of discharge.

* Disadvantages:- 1) Moving parts means high intial & cost
  2) High maintaince cost.
  3) No uniform torque
  4) Low discharging capacity
  5) Pulsating flow.
  6) Difficult to pump viscous fluid
  7) High & wear in parts.

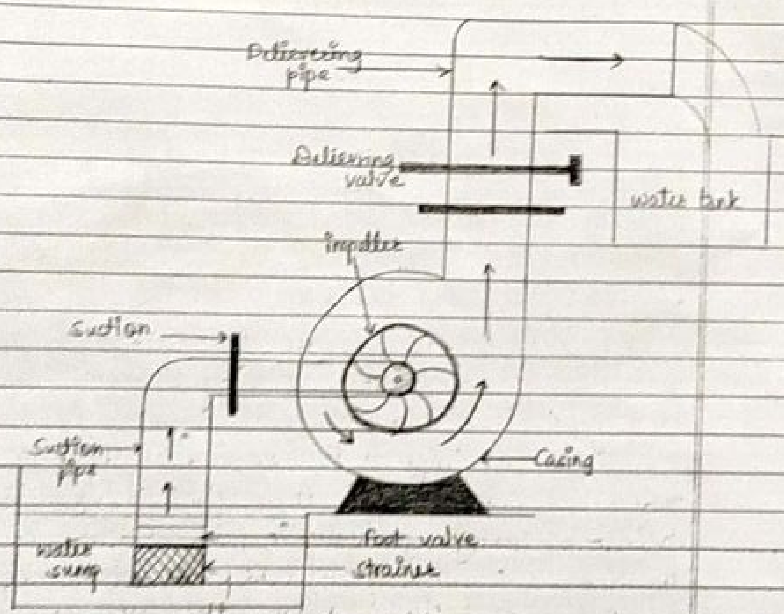
Working of Centrifugal pumps:-
Centrifugal pump is a hydraulic machine which converts mechanical energy into hydraulic energy (i.e pressure energy) by use of centrifugal force acting on fluid.
Components of centrifugal pump:-
1) Impeller
2) Casing
3) Suction pipe with foot valve & strainer
4) Delievery pipe

Working-
As the electric motor starts rotating, it also rotate the impeller. The rotation of impeller create suction of the suction pipe. Due to suction created the water from sump starts coming to causing thr eye of impeller.
From eye of impeller, due to centrifugal force acting on water, the water starts moving radialy outward and towards the outer of casing.
Since the impeller is rotating at high velocity it also rotates the water around it in the casing. The area of the casing increasing gradually in the direction of rotation so the velocity of the water keeps on decreasing & pressure increases, at outlet of pump the pressure is max.
Now from the outlet of pump, the water goes to its desired location thr delievery pipe.

* advantages:- 1) Steady delievery (uniform flow)
  2) Can handles all type of fluid
  3) Can be mounted horizontally or vertically

Page No. Date

- Disadvantages :-
1) Reducing performance when handling viscous fluid
2) can only handle small amounts of gases in liquid
3) Not effective for high velocities, but multistage configuration are expensive
4) Priming often needed before startup



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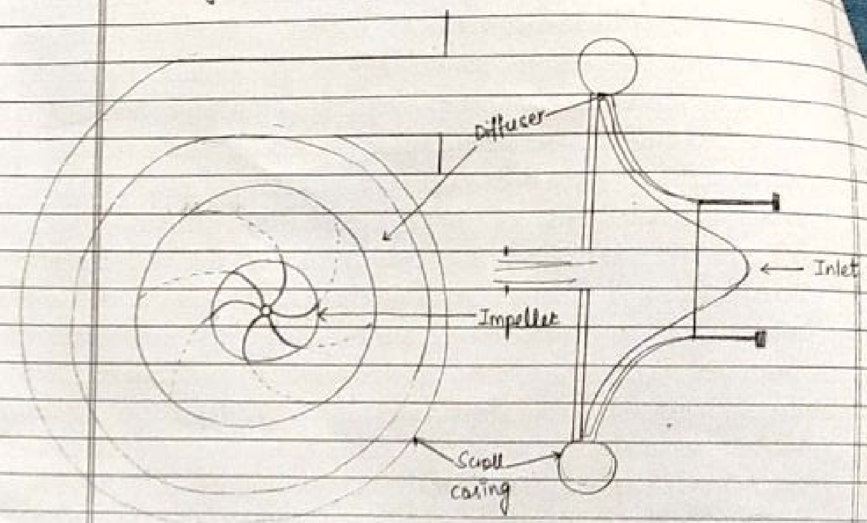
Working of centrifugal compressor:-

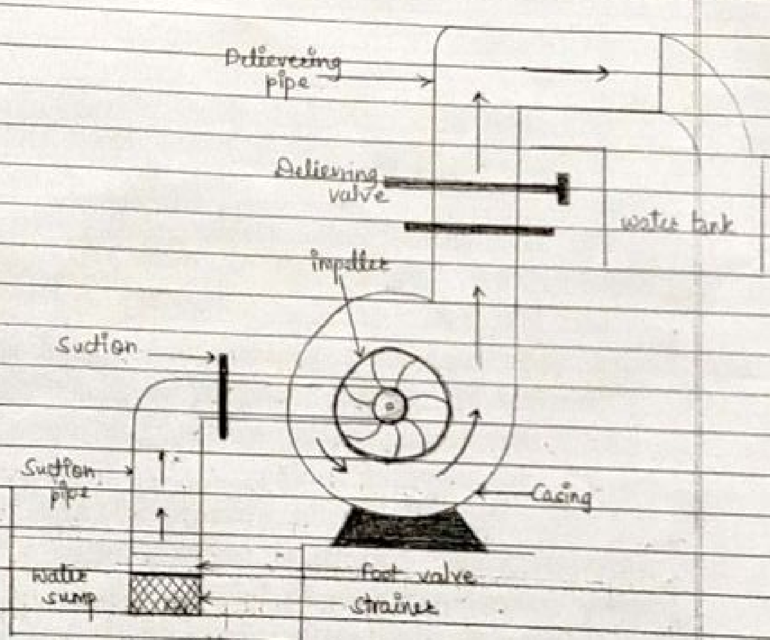


They work on the principle of conversion of the rotating KE into an increased static fluid pressure (pressure energy)

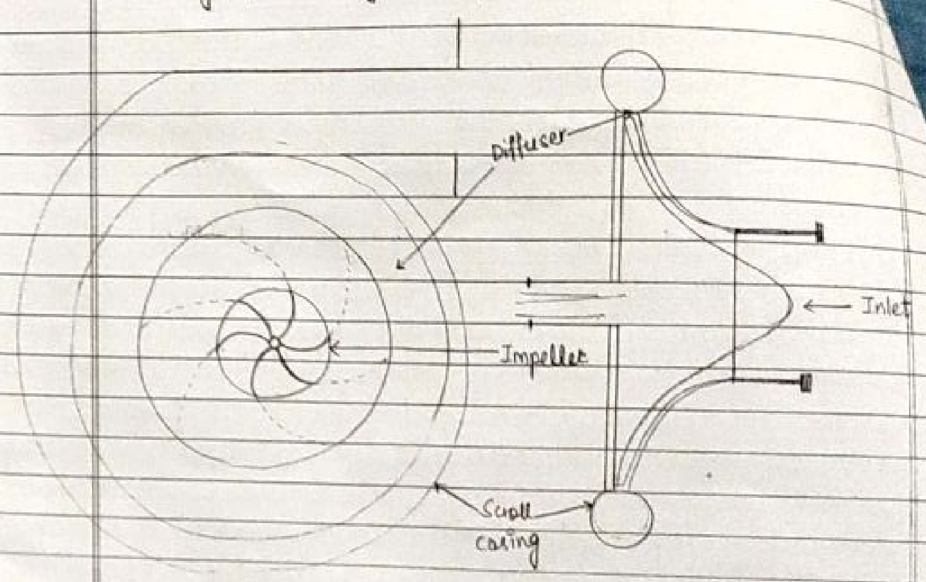
Working :- In centrifugal compressor, the impeller is connected to a shaft driven by any mechanism and it also consists diffuser enclosed in a scroll casing. By rotation of impeller a low pressure is created at impeller eye (centre) which the air into impeller. The impeller imparts KE to air forcing the fluid to move to periphery into diffuser. During the movement impeller increases KE of air. The diffuser guides the air & converts a part of KE into the scroll casing where remaining KE is converted into static pressure energy. the high pressure air is discharged thr the outlet.

* Disadvantages :-

1) Reducing performance when handling viscous fluid.
2) can only handle small amounts of gases in liquid
3) Not effective for high velocities but multistage configuration are expensive
4) Primarily often needed before startup.



Working of centrifugal compressor:-



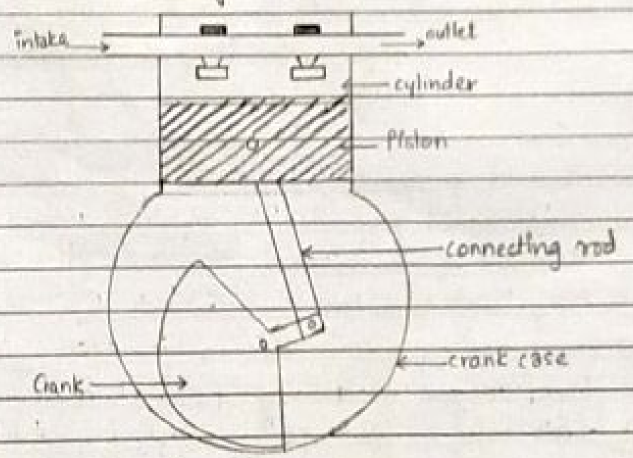
They work on the principle of conversion of the rotating KE into an increased static fluid pressure (pressure energy)

Working :- In centrifugal compressor, the impeller is connected to a shaft driven by any mechanism and it also consists diffuser enclosed in a scroll casing. By rotation of impeller a low pressure is created at impeller eye (centre) which the air into impeller. The impeller imparts KE to air forcing the fluid to move to periphery into diffuser. During the movemen impeller increases KE of air. The diffuser guides the air & converts a part of KE into the scroll casing where remaining KE is converted into static pressure energy the high pressure air is discharged thr the outlet.

* Advantages :- 1) High pressure ratios
  2) low wt. easy to design & manufacture
  3) Suitable for continuous compressed air supply such as cooling unit
  4) Oil free in nature.
  5) High flow rate than +ve displacement comp.

* Disadvantages :-
  1) They are sensitive to changes in gas composition
  2) Problem of surging, stalling & choking
  3) High initial cost.

* Working of Reciprocating Compressor :-



This type of compressor uses piston cylinder arrangement to compress the air.

Piston move back & forth inside the cylinder & compresses the air. There are 2 sets of valves that take air inside & exhaust.

The compressor takes inside successive amount of volume of the air from intake valve & certified it in close surface at that time piston moves downward with the closure of intake valve. Then there is compression of air by reducing its volume. Now the piston moves upward & compress the air and then displace the compressed air thr exhaust valve and then again intake take place & cycle repeat itself.

* Advantages :- 1) Relatively cheap
  2) Easy maintainance
  3) Suitable for high pressure.

* Disadvantages :- 1) Sounds too much
  2) High outlet temp of compressed air.
  3) High oil content in air piping.

* Selection of pumps :-
  1) Process liquid properties.
  2) Materials of construction
  3) Pump's inlet condition
  4) Pump's environment
  5) Power source availability
  6) Flow rate & pressure.

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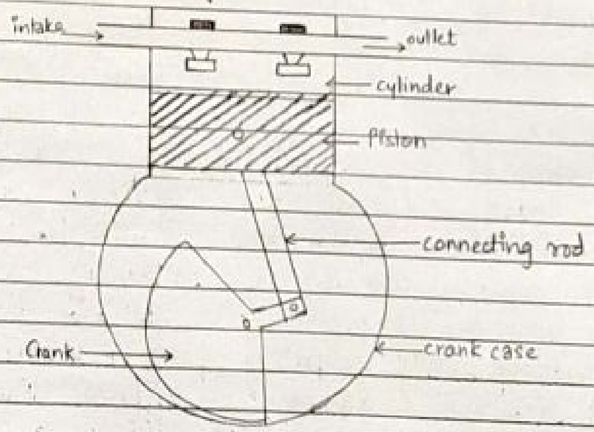

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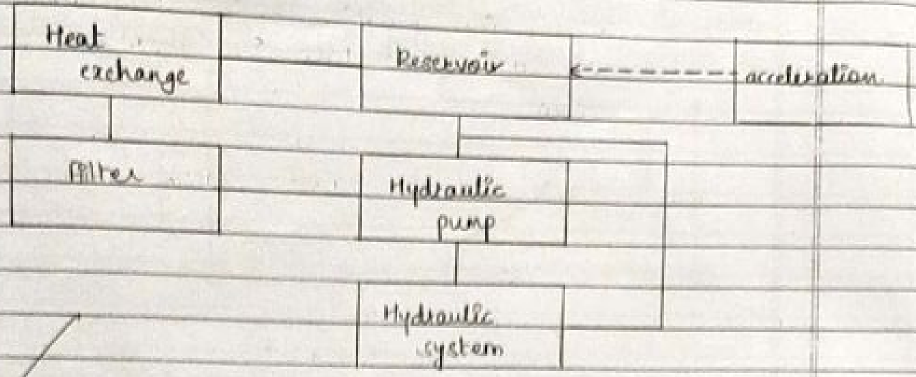
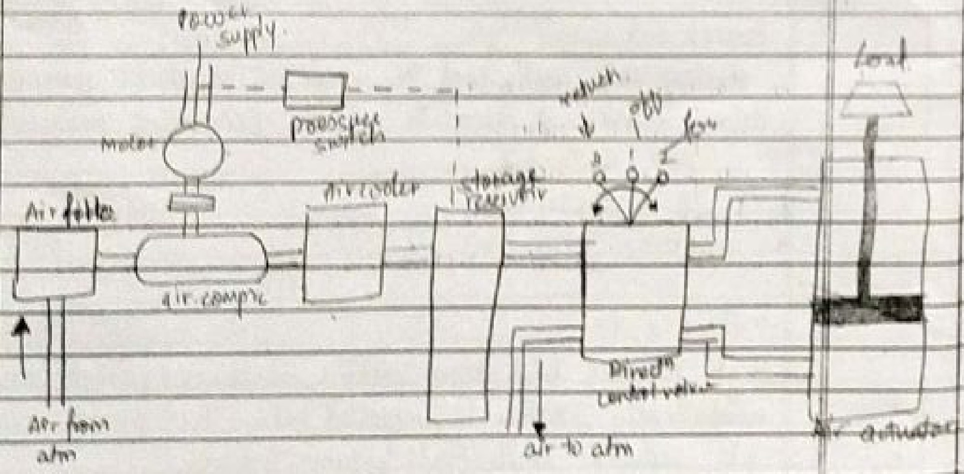
6) Flow rate & pressure.

* Block diagram of hydraulic system:-





comp of pneumatic system

2nd Module:-

Zeroth law :- A-B B-C A-C

1st law: Energy can neither be created nor be destroyed. It can be converted from one form to another form

1st law ⇒ cycle $\oint \delta Q = \oint \delta W \rightarrow \oint dQ = \oint dW$

1st law ⇒ process $Q - W = \Delta E$

$Q = \Delta E + W$

$Q - W = \Delta U \rightarrow$ internal energy

$\Delta E = Q - W$

Isolated system $Q = 0$ $W = 0$ ∴ $\Delta E = 0$ / constant

PMM-I → Imaginary device which delivers work without any input.

Perpetual motion machine

Limitations of 1st law:-

① It does not give the idea under which conditions heat-work interaction possible

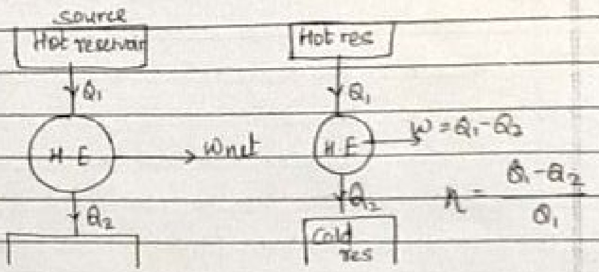
② no idea

2nd law of thermodynamics:-

Kelvin Plank's statement:-

connection with heat engine

It Impossible to heat engine which works continuously by interacting with only one reservoir.

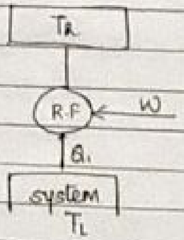


$$\eta = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta = \frac{\text{supplied} - \text{released}}{\text{supplied}}$$

Clausius statement :- (Heat pump & refrigerator)

It is impossible to exchange heat from lower temp to higher temp without any external agent



$$COP_{(Ref)} = \frac{T_L}{T_H - T_L} \qquad COP_{(HP)} = \frac{T_H}{T_H - T_L}$$

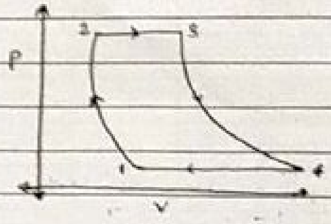
PMM-II :-

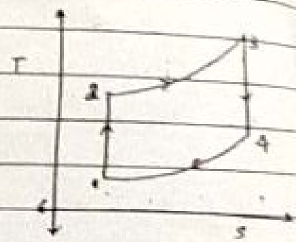
Imaginary machine / hypothetical machine which will deliever work continuously with interaction with only one reservoir.

* Gas law : Boyle's law ⇒ PV = cont.
  Charle's law ⇒ TV = cont.

Joule cycle :- (Brayton cycle)

This cycle consists of 2 adiabatic process case of otto cycle but heat addition & rejection at constant pressure rather than at constant volume





Process 1-2 :

At this process the working substance is compressed adiabatic. The temp & pressure gets raised adiabatic compression.

$W = -C_V(T_2 - T_1)$ $\quad \Delta U = Q - W$

$Q = 0$

$\Delta U = C_V(T_2 - T_1) \longrightarrow$ (gain)

Process 2-3 :

During this part heat is added at constant pressure. Due to this, volume & temp is raised. [constant pressure heating]

$W = R(T_3 - T_2)$

$Q = C_p(T_3 - T_2)$

$\Delta U = C_V(T_3 - T_2)$

Process 3-4 :

High pressure high temp working substance (gas) is expanded adiabatically. Work is expelled out. The pressure & temp gets reduced while the volume increases

$W = -C_V(T_4 - T_3)$

$Q = 0$

$\Delta U = C_V(T_4 - T_3) \longrightarrow$ (loss)

Process 4-1 : The low pressure, high volume gas is brought back to original state by cooling it at constant pressure. Volume gets reduced.

4-1 const pressure cooling

$W = R(T_1 - T_4)$

$Q = C_p(T_1 - T_4)$

$\Delta U = C_v(T_1 - T_4)$

Net work output = Heat supplied - Heat rejected.

$= C_p(T_3 - T_2) - |C_p(T_1 - T_4)|$

$= C_p(T_3 - T_2) - C_p(T_4 - T_1)$

$$\text{Efficiency} = \frac{\text{work output}}{\text{heat input}}$$

$$= \frac{C_p(T_3 - T_2) - C_p(T_4 - T_1)}{C_p(T_3 - T_2)}$$

$$= 1 - \frac{T_4 - T_1}{T_3 - T_2}.$$

At adiabatic compression we have,

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \quad \& \quad \frac{P_2}{P_1} = \frac{T_2}{T_1} \times \frac{V_1}{V_2}$$

$$\frac{P_2}{P_1} = r_p = \text{pressure ratio}$$

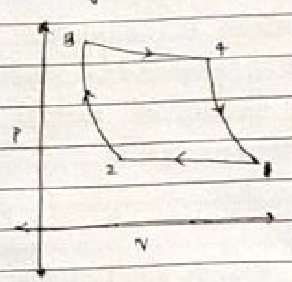
$$\frac{T_1}{T_2} = \left(\frac{1}{r_p}\right)^{\frac{\gamma-1}{\gamma}}$$

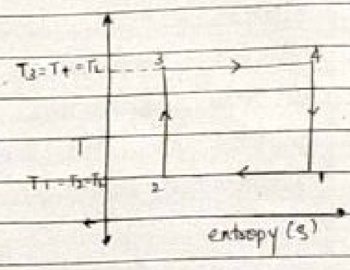
Similarly $\frac{T_4}{T_3} = \left(\frac{1}{r_p}\right)^{\frac{\gamma-1}{\gamma}}$

$$\frac{T_4 - T_1}{T_3 - T_2} = \left(\frac{1}{r_p}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\eta = 1 - \left[\frac{1}{r_p}\right]^{\frac{\gamma-1}{\gamma}}$$

Carnot Cycle :- (Standard air cycle) → no phase change





The Carnot cycle consists of 4 processes arranged in a cyclic manner which are represented on pressure-volume and temperature entropy diagram.

Process 1-2 : At this process working medium is compressed isothermally. This part of cycle is performed at the cost of external work taken from the surrounding

$\therefore W = P_1 V_1 \log\left(\frac{V_2}{V_1}\right) \Rightarrow \Delta V = 0; \; T_1 = T_2$

$= RT_1 \log_e \frac{V_2}{V_1}$

$Q = RT_1 \log_e \frac{V_2}{V_1}$ (Q rejected)

$\therefore \Delta U = 0$ as the process is isothermal

Process 2-3 : At this part the working medium is further compressed adiabatically. This part of cycle is also at the cost of receipt of external work from surrounding since heat transfer is not permissible, the entropy remains same.

adiabatic compression -

$Q - W = \Delta U$; $\boxed{\Delta Q = 0}$

$W = -C_v(T_3 - T_2)$

$\therefore \quad \Delta U = C_v(T_3 - T_2)$

Process 2-4 : Working medium is expanded isothermally. A large amount of work is produced & delivered out. At this expansion large amount of heat is to be received in. The temp. remains same.

Isothermal expansion -

$$W = P_3V_3 \log_e \frac{V_4}{V_3} = RT_3 \log_e \left(\frac{V_4}{V_3}\right)$$

$$Q_2 = RT_3 \log\left(\frac{V_4}{V_3}\right) = Q\text{(added)}$$

$\Delta U = 0$ as it is isothermal

Process 4-1 : The working medium is expanded adiabatically to reach the starting stage. At this stage large amount of work is obtained without any heat transfer at the cost of loss of internal energy

Adiabatic expansion -

$$W = -C_v(T_1 - T_4) \quad ; \quad Q = 0$$

$$\Delta U = C_v(T_1 - T_4)$$

Net change in internal energy $= C_v(T_3 - T_2) - |C_v(T_4 - T_1)|$

$T_3 = T_4 \ \& \ T_1 = T_2$

$\Delta U = 0$

Net work transfer $= Q_{added} - Q_{rejected}$

$$= |Q_3 - Q_4| - |Q_1 - Q_2|$$

$$= \left|RT_3 \log_e \frac{V_4}{V_3} - 0\right| - \left|RT_1 \log_e \frac{V_2}{V_1} - 0\right|$$

$$W_{net} = RT_3 \log_e \frac{V_4}{V_3} - RT_1 \log_e \frac{V_1}{V_2}$$

$$W_{net} = R(T_3 - T_1) \log_e \frac{V_4}{V_3} \quad \because \frac{V_4}{V_3} = \frac{V_1}{V_2}$$

$$\eta_{carnot} = \frac{R(T_3 - T_1)\log_e V_4/V_3}{R\, T_3 \log_e(V_4/V_3)} \Rightarrow \left(\frac{\text{work o/p}}{\text{Heat i/p}}\right)$$

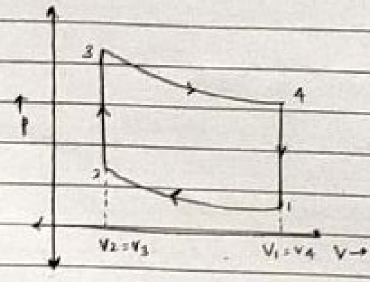
$$= \frac{T_3 - T_1}{T_3}$$

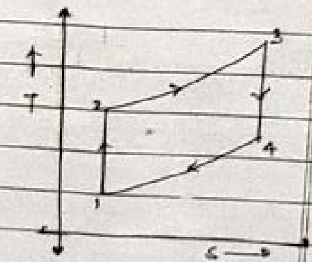
$$= \frac{T_H - T_L}{T_H}$$

$$\eta = 1 - \frac{T_L}{T_H} \Bigg/ 1 - \frac{T_1}{T_3}$$

Otto Cycle :-

Otto cycle consist of 4 processes out of which two are constant volume processes & 2 are adiabatic process.





Process 1-2 : adiabatic compression. air is compressed from volume V_1 to V_2 by the work done on system.

* Adiabatic compression -

$Q - W = \Delta U$

$W = -C_v(T_2 - T_1)$ — work in

$Q = 0$

$\Delta U = C_v(T_2 - T_1)$ — gain in energy

Process 2-3 : This part of cycle is constant volume heat addition process. At the end of this, max pressure gets developed

$W = 0$

$Q = C_v(T_3 - T_2)$

$\Delta U = C_v(T_3 - T_2)$ — gain

Process 3-4 :

During this part air is expanded adiabatically to original volume. As a result, work is delivered out of the cost of loss of internal energy

Adiabatic expansion -

$W = -C_v(T_4 - T_3); \; Q = 0$

$\Delta U = C_v(T_4 - T_3)$

Process 4-1 :

During this part, the air is cooled to reduce its pressure to starting stage.

$W = 0$

$Q = C_v(T_1 - T_4)$

$\Delta U = C_v(T_1 - T_4)$ — loss.

$\therefore$ Net work output $= C_v(T_3 - T_2) - C_v(T_4 - T_1)$

$= C_v[(T_3 - T_2) - (T_4 - T_1)]$

Heat Input $= C_v(T_3 - T_2)$

Efficiency $(\eta) = \dfrac{C_v[(T_3 - T_2) - (T_4 - T_1)]}{C_v[T_3 - T_2]}$

$= 1 - \dfrac{T_4 - T_1}{T_3 - T_2}$

For process 1-2 we have -

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$\therefore \dfrac{P_1}{P_2} = \left(\dfrac{V_2}{V_1}\right)^{\gamma}$ — ①

$PV = nRT$

also,

$\dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2}$

$\dfrac{P_1}{P_2} = \dfrac{V_2}{V_1} \times \dfrac{T_1}{T_2}$ — ②

$\therefore \dfrac{T_1}{T_2} = \left(\dfrac{V_2}{V_1}\right)^{\gamma - 1}$ — from ① & ②

Similarly -

$\dfrac{T_4}{T_3} = \left(\dfrac{V_3}{V_4}\right)^{\gamma - 1} = \left(\dfrac{V_2}{V_1}\right)^{\gamma - 1}$

$\therefore \dfrac{T_1}{T_2} = \dfrac{T_4}{T_3} = \dfrac{T_4 - T_1}{T_3 - T_2}$

$\eta_{otto} = 1 - \dfrac{T_1}{T_2} = 1 - \left(\dfrac{V_2}{V_1}\right)^{\gamma - 1} = 1 - \dfrac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma - 1}}$

let, $\dfrac{V_1}{V_2} = r$ = compression ratio

$\eta_{otto} = 1 - \dfrac{1}{(r)^{\gamma - 1}}$

* Kelvin - Plank Statement :-

It is impossible for heat engine to produce net work in a complete cycle if it exchanges heat only with bodies at a single, fixed temperature

* Clausius statement :-

It is impossible to construct a device that operates in a cycle & produces no effect other than the transfer of heat from a lower temp body to higher temp. body.

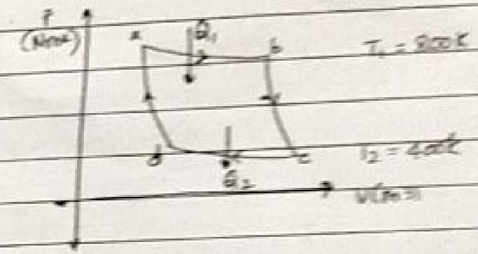
* Perpetual Motion Machine of second kind (PMM-2)

PMM-2 is an imaginary engine that while working in cycle, converts all the heat input into work. As per second law of thermodynamics, the existence of PPM-2 is impossible

Problems :-

Carnot Cycle :-

Q.1. If heat absorbed by the engine $(Q_1) = 10000$ Joule what is the work done by the carnot engine?



→ low temp $(T_2) = 400K$

high temp $(T_1) = 800K$

Heat input $Q_1 = 10000$ J

Work done by engine $= w = ?$

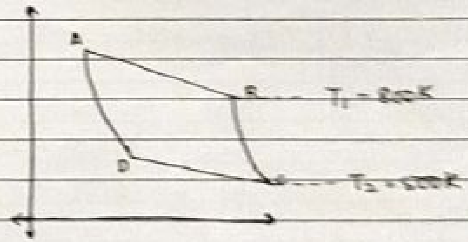
$$\eta_{carnot} = \frac{T_H - T_L}{T_H} = \frac{T_1 - T_2}{T_1} = \frac{800-400}{800}$$

$$\eta_{carnot} = 0.5$$

$$w = \eta \cdot Q = 0.5 \times 10000 = 5000 \text{ J}$$

Q.2 If heat rejected is 3000 J, then what is the heat added?

$\eta = 3/8$



→ $T_H = 800K$; $T_L = 500K$

$Q_2 = 3000$ J

$Q_1 = ?$

$w = \eta Q_{added}$

$\eta = \frac{T_H - T_L}{T_H} = \frac{800-500}{800} = \frac{3}{8}$

$w = \frac{3}{8} Q_1$

but we know that

$w = Q_{added} - Q_{rejected}$

$= Q_1 - Q_2$

$w = \frac{8}{3} w - Q_2$

$\therefore Q_2 = \frac{8}{3} w - w$

$Q_2 = \frac{5}{3} w$

$\therefore w = \frac{3Q_2}{5} = \frac{3 \times 3000}{5} = 1800$

Now, $Q_1 = w + Q_2 = 1800 + 3000 = 4800 J$

$\therefore$ Heat added = 4800 J.

Otto cycle :-

Q. 1. In an air standard Otto Cycle, the compression ratio is 7 and the compression begins at 35°c and 0.1 MPa. The max temp of cycle is 1100°c. Find

a) Temp & pressure at various points in cycle
b) Heat supplied per kg of air
c) Work done per kg of air
d) Cycle efficiency

→

$T_1 = 30°c = 303 K$

$P_1 = 10^5 Pa$

$T_3 = 1100°c = 1373 K$

$r = V_1/V_2 = 7$

a) ⇒ $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = (r)^{\gamma} = 7^{1.4} = 15.24$

$P_2 = 15.24 \times 10^5 Pa = 1524 kPa$

$\frac{T_2}{T_1} = (r)^{\gamma-1} = 7^{1.4-1} = 2.178$

$T_2 = 670.8 K$

$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$

$\therefore P_3 = \frac{P_2 T_3}{T_2} = \frac{1524 \times 1373}{670.8} = 3119.34 kPa$

$P_3 = 3119.34 kPa$

$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = 7^{1.4-1} = 2.178$

$T_4 = 630.39 K$

$W = \eta Q_{added}$

$\eta = \frac{T_H - T_L}{T_H} = \frac{800-500}{800} = \frac{3}{8}$

$W = \frac{3}{8} Q_1$

but, we know that

$W = Q_{added} - Q_{rejected}$

$= Q_1 - Q_2$

$W = \frac{8}{3} W - Q_2$

$\therefore Q_2 = \frac{8}{3} W - W$

$Q_2 = \frac{5}{3} W$

$\therefore W = \frac{3Q_2}{5} = \frac{3 \times 3000}{5} = 1800$

Now, $Q_1 = W + Q_2 = 1800 + 3000 = 4800\,J.$

$\therefore$ Heat added = 4800 J.

Otto cycle :-

Qn. 1. In an air standard Otto cycle, the compression ratio is 7 and the compression begins at 35°c and 0.1 MPa. The max temp of cycle is 1100°c. Find.

a) Temp & pressure at various points in cycle.
b) Heat supplied per kg of air
c) Work done per kg of air.
d) Cycle efficiency

→

$T_1 = 35°C = 308\,K.$

$P_1 = 10^5\,Pa$

$T_3 = 1100°C = 1373\,K$

$r = V_1/V_2 = 7.$

a) ⇒ $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = (r)^{\gamma} = 7^{1.4} = 15.24$

$P_2 = 15.24 \times 10^5\,Pa = 1524\,kPa$

$\frac{T_2}{T_1} = (r)^{\gamma-1} = 7^{1.4-1} = 2.178$

$T_2 = 670.8\,K.$

$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$

$\therefore P_3 = \frac{P_2 T_3}{T_2} = \frac{1524 \times 1373}{670.8} = 3119.34\,kPa$

$P_3 = 3119.34\,kPa$

$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = 7^{1.4-1} = 2.178$

$T_4 = 630.39\,K$

b) Heat supplied $= C_v(T_3 - T_2)$

$= 0.718(1372 - 670.8)$

$= 509.12 \text{ kJ/kg}$

Heat rejected $= C_v(T_4 - T_1)$

$= 0.718(630.39 - 298)$

$= 231.44 \text{ kJ/kg}$

c) $W_{net} = Q_{in} - Q_{out}$

$= 272.70 \text{ kJ/kg}$

d) Cycle efficiency -

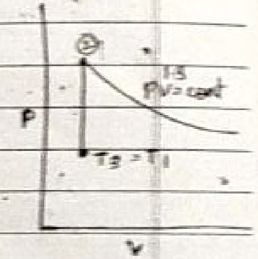
$$\eta_{otto} = 1 - \frac{1}{(8)^{\gamma-1}}$$

$$= 1 - \frac{1}{(7)^{1.4-1}}$$

$$= 0.54$$

$\eta_{otto} = 54\%$

Certain quantity of air has a volume of $0.028 m^3$ at a pressure of 1.25 bar & compressed to a volume of $0.0042 m^3$ at a temp of $T_1 = 25°C$ according to law $PV^{1.3} = const$ $(\gamma = 1.3)$. Find temp & workdone during compression also determine reductn in pressure at constant volume required to bring the air to its initial temp.



$$P_1 V_1^{1.3} = P_2 V_2^{1.3}$$

$$1.25(0.028)^{1.3} = P_2(0.0042)^{1.3}$$

$$P_2 = \frac{1.25(0.028)^{1.3}}{(0.0042)^{1.3}}$$

$\therefore P_2 = 14.72 \text{ bar}$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1.25 \times 0.028}{298} = \frac{14.72 \times 0.0042}{T_2}$$

$T_2 = 526 K$

$$\frac{P_2}{P_3} = \frac{T_2}{T_3}$$

$$\frac{14.72}{P_3} = \frac{526}{298}$$

$P_3 = 8.33$

$$W_{1-2} = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{1.25 \times 0.028 - 14.72 \times 0.0042}{1.3 - 1}$$

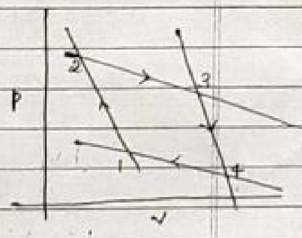
$W_{1-2} = -0.089$

A carnot cycle works with isentropic ratio of 5 & isothermal ratio 2.
volume of the air at the beginning of the isothermal expansion is 0.3 m³ if max temp & pressure is limited to 550 K. & 21 bar determine

1) min temp
2) Thermal efficiency
3) Pressure at all ~~silent~~ saddle points

$\boxed{\gamma = 1.4}$

→ $\frac{V_1}{V_2} = \frac{V_4}{V_3} = 5$



$\frac{V_3}{V_2} = \frac{V_4}{V_1} = 2$

$P_2 = 21$ bar

$V_2 = 0.3\ m^3$

$V_1 = 1.5\ m^3$; $V_3 = 0.6\ m^3$; $V_4 = 3\ m^3$;

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

$P_1 (1.5)^{1.4} = 21 (0.3)^{1.4}$

$P_1 = 2.20$ bar

$P_2 V_2^{\gamma} = P_3 V_3^{\gamma}$

$21 (0.3)^{1.4} = P_3 (0.6)^{1.4}$

$P_3 = 10.5$ bar

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$P_4 V_4 = P_1 V_1$

$P_4 = 1.1$ bar

$\frac{2.2 \times 1.5}{T_1} = \frac{21 \times 0.3}{550}$

$\boxed{T_1 = 288.09\ K.}$

$\eta = \frac{T_2 - T_1}{T_2} = 0.47 = 47\%$

that has heat addition $(Q_1) = 2800$ kJ/kg & $r = 8$ pressure & temp at beginning ($P_1 = 1$ bar, $T_1 = 300K$) Determine

1) max P & T in cycle
2) Thermal efficiency
3) Mean effective pressure

$C_p = 1.005$ kJ/kg.K ; $C_v = 0.718$ kJ/kg.K

$R_{cont} = 0.287$ kJ/kg K.

→ $\gamma = 1.4$

$\eta_{otto} = 1 - \frac{1}{(r)^{\gamma - 1}}$

$= 0.56$

$W = \eta_{otto} Q = 0.56 \times 2800 = 1568$ kJ/kg.

$\frac{V_1}{V_2} = 8$

$\boxed{V_1 = 8V_2}$

$\frac{T_2}{T_1} = 8^{\gamma-1} = 8^{0.4}$

$T_2 = 689\ K.$

$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$

$\frac{P_1}{P_2} = \left(\frac{1}{8}\right)^{1.4}$

$P_2 = 8^{1.4} P_1 = 18.37$ bar

Q supplied at const volume $= m C_v (T_3 - T_2)$

$2800 = 1 \times 0.718 (T_3 - 689)$

$T_3 = 4588\ K.$

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$$\frac{P_2}{T_2} = \frac{P_3}{T_3}$$

$$P_3 = \frac{18.37 \times 4588}{689}$$

$$P_3 = 122.32 \text{ bar}$$

$\frac{\times 10^5}{10^3}$

$$P_2 V_2 = R T_2$$

$$V_2 = \frac{10.76 \times 10^5}{10^5}$$ pressure conversion (bar → newton)

$$V_2 = 0.1076 \text{ m}^3$$

$$MEP = \frac{\text{Workdone/ cycle}}{V_1 - V_2} = \frac{1568}{7 \times 0.1076} = 2081.78$$

Saturated liquid :- so much of solute at that temp that it can dissolve no more

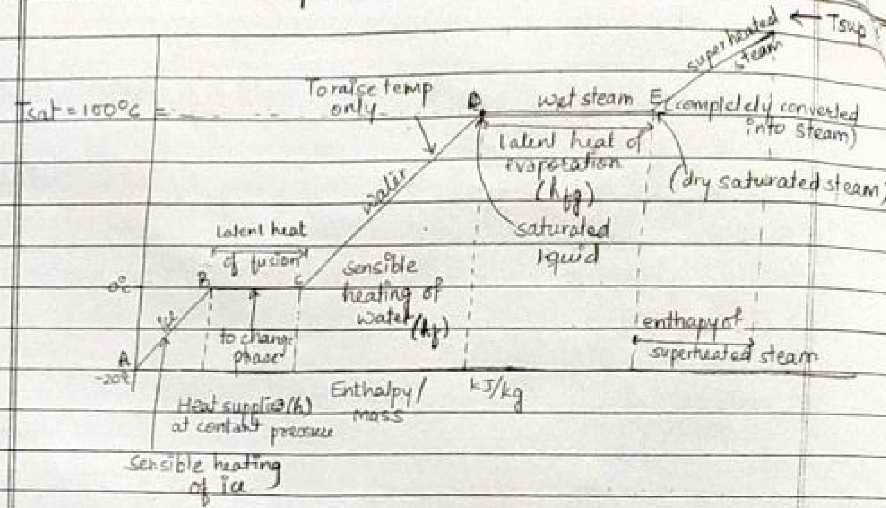
Uses of steam (Applicaⁿ)
formation
wet steam -
Dryness fra-

Saturated pressure :- it is pressure which is in equilibrium with its liquid

saturated vapour :- it is a state at saturation temp for particular pressure where all the liquid is converted into vapour

Module :- 4

Properties of Steam



★ Sensible Heat :-

The amount of heat required to raise the temp. of 1 kg of water from 0°c to saturated temp. at given pressure.

★ Saturation temp -: (T_s)

The temp. at which water starts boiling at the respective pressure [reduce pressure ⇒ boil at less temp ...

★ Latent Heat -: (fusion, evapouration)

Heat utilised to change the phase.

★ Degree of superheat -: ~~diff~~ betⁿ superheated temp & saturatio temp.
= ($T_{sup} - T_{sat}$)

★ Wet steam -:

quality depends on water particles amount & it is defined by the dryness fraction.