SUMMER – 15 EXAMINATION

Subject Code: 17406 (HE) **Model Answer**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.

2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.

3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills.

4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.

5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate͛s answers and model answer.

6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate͛s understanding.

7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1 – (a) i) (Two marks)

Following are the different sources of energy

- Primary and Secondary energy sources
- Commercial and Noncommercial energy sources
- Renewable and Nonrenewable energy sources

Q.1 – (a) ii)

Thermodynamic System: - (one mark for definition and one for classification)

It is defined as quantity of matter or a region in space upon which attention is focused foe study or analysis of problem.

OR

Thermodynamic system may be broadly defined as area or a space where thermodynamic process takes place.

OR

The term system is defined as a specified region where transfer of energy or mass takes place.

Classification of system: -

1. Closed system
2. Open system
3. Isolated system

Q.1 – (a) iii) Properties of system (1/2 mark each for definition and examples)

Intensive property: - The properties which do not depend upon the mass of the system. e.g. Pressure, Temperature, density etc.

Extensive Property: - The properties which depends on the mass of the system.
e.g. total volume, enthalpy, entropy etc.

Q.1 – (a) iv) (One mark for each law)

Boyle's Law- The law states that the volume of a given mass of a perfect gas varies **inversely** with absolute pressure when the temperature remains constant.

Let,
P = Absolute pressure of the gas
V = Volume of the gas at pressure P
Then according to this law,

$$V \alpha 1/P$$

Charles's law: It states that if a perfect gas is heated at constant pressure, its volume varies directly with the absolute temperature.

At constant pressure, V α T, when P = c

$\frac{?}{?}$ = constant

Q.1 – (a) v) (one mark for each definition)

Latent Heat- The quantity of heat required in kJ to convert 1 kg of water at its saturation temperature for a given pressure, to 1 kg of dry saturated steam is known as latent heat.

Sensible Heat- The quantity of heat required to raise the temperature of 1 kg of water from 0 ^{0}c to the boiling point temperature corresponding to the given pressure.

Q.1 – (a) vi) (one mark for each explanation)

Two stroke engine – The cycle is completed in two strokes of the piston or in one revolution of the crankshaft. Thus one power stroke is obtained in each revolution of the crank shaft.

Four stroke engine - The cycle is completed in four strokes of the piston or in two revolutions of the crankshaft. Thus one power stroke is obtained in every two revolutions of the crank shaft.

Q.1 – (a) vii) Following are the uses of compressed air- (Any Four ½ marks each)

1) To drive air motors in coal mines.
2) To inject fuel in air injection diesel engines.
3) To operate pneumatic drills, hammers, hoists, sand blasters.
4) In gas turbine plants.
5) For cleaning purposes.

6) To cool large buildings and aircrafts.
7) In the processing of food and farm maintenance.
8) In vehicle to operate air brake.
9) For spray painting in paint industry.

Q.1 – (a) viii) (one mark for each definition)

Coefficient of performance : It is defined as the ratio of amount of heat removed from cold reservoir to the amount of work supplied

Co-efficient of performance, $(C.O.P.)_{ref.} = Q/W$

where, Q = Heat transfer from cold reservoir, and

W = The net work transfer to the refrigerator.

The COP has no units.

Tonne of refrigeration – It is defined as the quantity of heat to be removed in order to form one ton of ice within 24 hr when the initial condition of water is zero degree centigrade, and is equivalent to 210 kJ/min

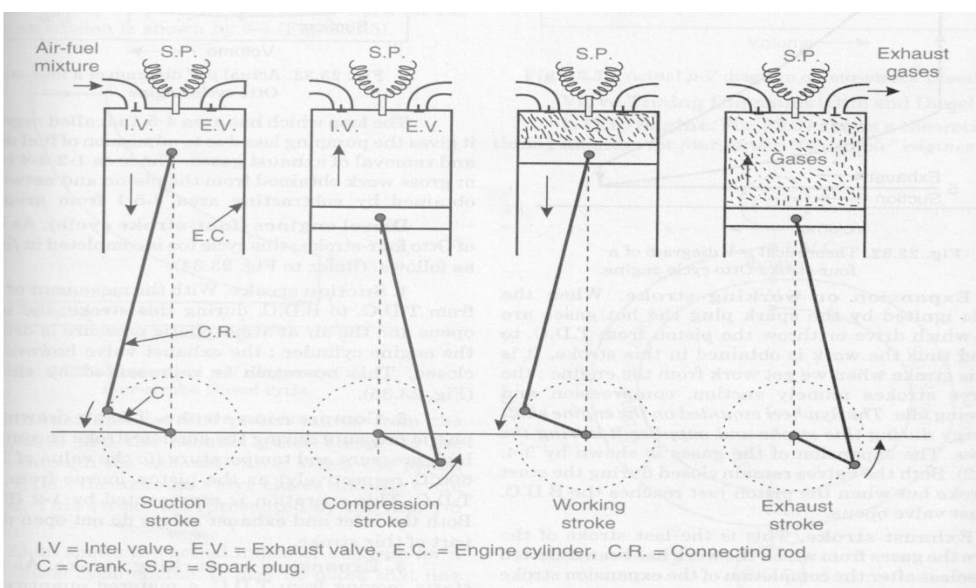
Q.1 – (b) (Two marks for each explanation and difference)

Polytropic Process- A process which follows the general law $PV^n = constant$, is known as polytropic process. Here n is the index of expansion or compression. The value of n varies from **0 to ∞.**

An adiabatic process is one during which there is no heat transfer between the system and the surroundings when work is done by the gas or on the gas. The equation is $PV^\gamma = constant$ where $\gamma = 1.4$.

Q.1 – (b) ii) (Two marks for figure and two for explanation)

Working of Four stroke petrol engine:



1. **Suction stroke**: Suction stroke starts when piston is at top dead center and about to move downwards. During suction stroke inlet valve is open and exhaust valve is closed. Due to low pressure created by the motion of the piston towards bottom dead center, the charge consisting of fresh air mixed with the fuel is drawn into cylinder. At the end of suction stroke the inlet valve closes.

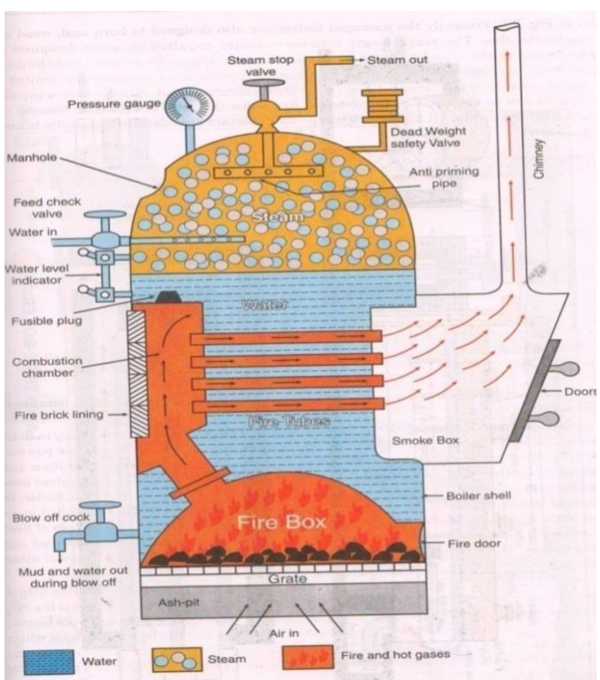
2. **Compression stroke**: During compression stroke, the compression of charge takes place by return stroke of piston, i.e. when piston moves from BDC to TDC. During this stroke both, inlet and exhaust valve remain closed. Charge which is occupied by the whole cylinder volume is compressed up to the clearance volume. Just before completion of compression stroke, a spark is produced by the spark plug and fuel is ignited. Combustion takes place when the piston is almost at TDC.

3. **Expansion or power stroke**: Piston gets downward thrust by explosion of charge. Due to high pressure of burnt gases, piston moves downwards to the BDC. During expansion stroke both inlet and exhaust valves remains closed. Thus power is obtained by expansion of products of combustion. Therefore it is also called as 'power stroke'. Both pressure as well as temperature decreases during expansion stroke.

4. **Exhaust stroke**: At the end of expansion stroke the exhaust valve opens, the inlet valve remains closed and the piston moves from BDC to TDC. During exhaust stroke the burnt gases inside the cylinder are expelled out. The exhaust valve closes at the end of the exhaust stroke but still some residual gases remains in cylinder.

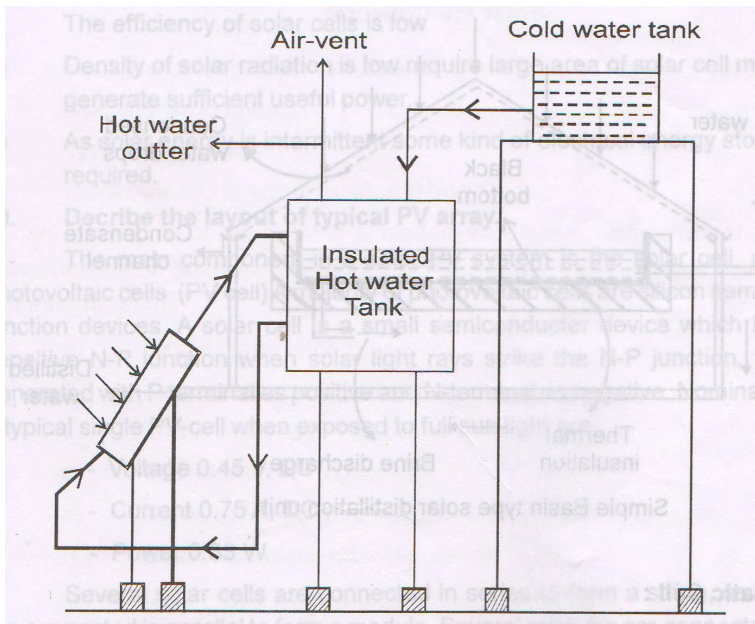
Q.1 – (b) iii) (Three marks for figure and one for labeling)

Labeled sketch of Cochran Boiler :



Q2 – (a) (Two marks for figure and two for explanation)

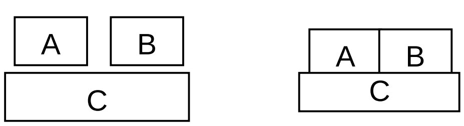
Solar water heater: A tilted flat plate solar collector with water as heat transfer fluid is used in solar water heater system. A thermally insulated hot water storage tank is mounted above the collector. The heated water of the collector rises up to the hot water tank and equal quantity of cold water enters the collector. The cycle repeats, resulting in all the water of the hot water tank getting heated up. When water is taken out from hot water outlet, the same is replaced y cold water from cold water tank, fixed above the hot water tank.



Solar water heater

Q2 – (b) (Two marks for each law)

Zeroth low of thermodynamic



Zeroth law of thermodynamic states that "If two systems are each in thermal equilibrium with a third system, then they are also in thermal equilibrium with each other.

Let 'A', 'B' & 'C' are three bodies at different temperature if 'A' & 'C' are brought into contact, energy in term of heat will from a body at higher temperature to body at lower temperature. After some time they will be in thermal equilibrium. Now if 'B' & 'C' are brought in good contact after some time they will be in thermal equilibrium. Then 'A' & 'B' are also in thermal equilibrium.

First Law of Thermodynamics: - It states that if a system executes a thermodynamic cycle, transferring work and heat through its boundary then the net heat transfer is equivalent to the net work transfer.

or $$\oint dQ = \oint dW$$

where $\oint$ represents the sum for a complete cycle.

Q2 – (c)

Q2 (c)

$V_1 = 0.1\ m^3$ $T_1 = 20^\circ c = 293^\circ K$

$P_1 = 1.5$ bar, $P_2 = 7.5$ bar

$V_2 = 0.04 m^3$ $T_2 = ?$

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

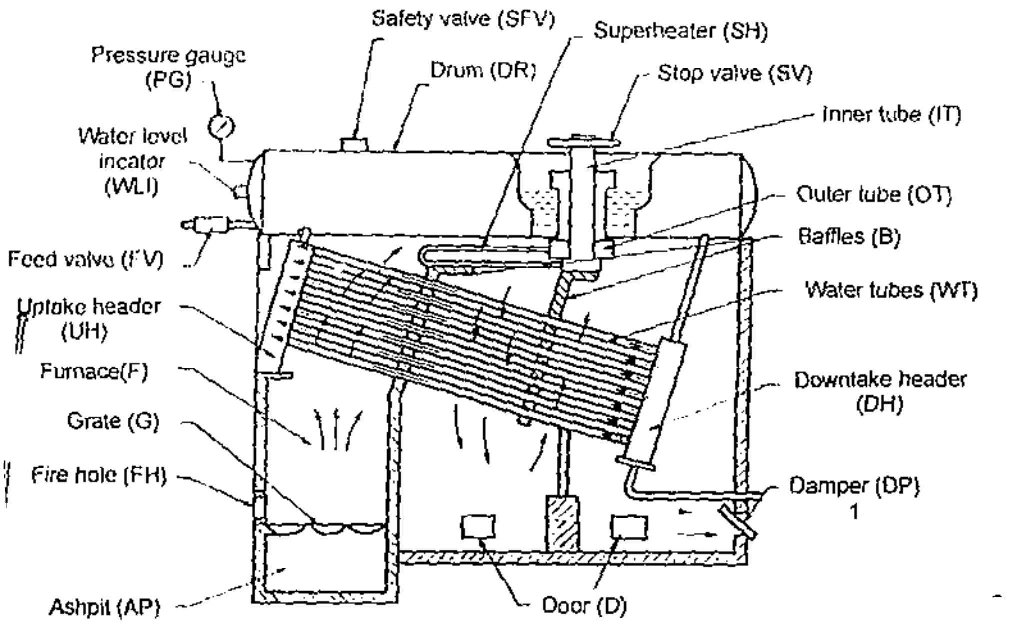
$$T_2 = \frac{P_2 V_2 T_1}{P_1 V_1} = \frac{7.5 \times 0.04 \times 293}{1.5 \times 0.1}$$

$$= 586^\circ K$$

Final temp. of gas = $586^\circ K$

Q2 – (d) (Three marks for figure and one for labeling)

Babcock and Wilcox boiler.

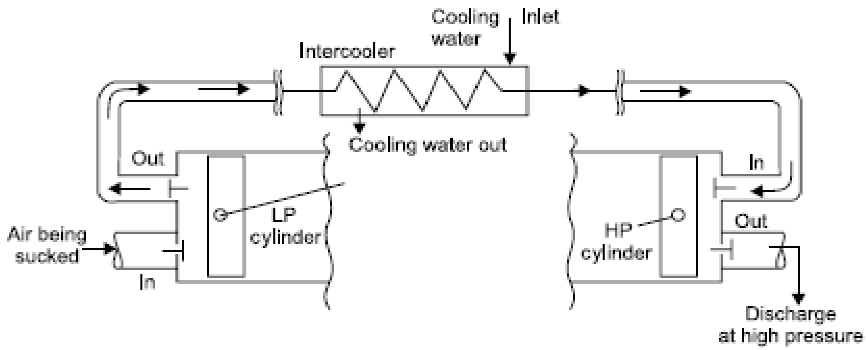


Q2 – (e) Comparison between two –stroke & four stroke engines. (any four points – 4 marks)

Four stroke engines	Two stroke engines
1) Cycle is completed in two revolution of crank shaft.	1) Cycle is completed in one revolutions of crank shaft.
2) One power stroke is obtained in every two revolution of crank shaft.	2) One power stroke is obtained in every revolution of crank shaft.
3) Because of one power stroke for two revolutions, power produced for same size engine is small or for same power engine is bulky.	3) Because of one power stroke for one revolution, power produced for same size engine is more. Theoretically twice but in actual practice 1.7 to 1.8 times or for same power, engine is light and compact.
4) Engine contains valves & valve mechanism.	4) Do not contain valves but only ports are present.
5)Heavier flywheel required	5) Lighter flywheel required.
6) Initial cost is high because of heavy weight and complicated valve mechanism.	6) Initial cost is low because of light weight and no valve mechanism.
7) Thermal efficiency is more.	7) Thermal efficiency is less.
8) Used where efficiency is important. e.g. bus , truck, tractor	8) Used where light and compact engine is required. e.g. scooters, lawn movers.

Q2 – (f) (Two marks for figure and two for explanation)

Two stage reciprocating air compressor :



Two stage reciprocating compressor

Multistage compression refers to the compression process completed in more than one stage i.e. a part of compression occurs in one cylinder (L.P. cylinder) and subsequently compressed air is sent to subsequent cylinders (H.P. cylinder) for further compression.

Figure shows the schematic of two stage compressor with intercooler between stages. The total work requirement for running this shall be algebraic summation of work required for low pressure (LP) and high pressure (HP) stages. The size of HP cylinder is smaller than LP cylinder as HP cylinder handles high pressure air having smaller specific volume.

Q3 – (a) (Any four points, one mark each) (Any four points – 4 marks)

Difference between thermodynamic heat and work

Sr. No.	Heat (Q)	Work (W)
1	It occurs due Temperature difference	It occurs due to Displacement or motion
2	Here is no restriction for transfer of heat	In stable system work transfer will be zero
3	The sole effect external to system could be reduced to raise the weight but heat transfer of the effect are also consider	The sole effect external to the system could be reduced to rise of a weight
4	Body or system contain heat	Body or system never contain work
5	Heat is low grade energy	Heat is high grade energy
6	Entire heat cannot be converted into work	Entire work can be converted into heat

7	Heat Received by system is consider as Positive (+Q)	Work done on the System is consider as Negative (-W)
8	Heat rejected by system is consider as Negative (-Q)	Work done by the System is consider as Positive (+W)
9	Application :- Any example related from Conduction, Convection or Radiation	Application :- Any example were force and displacement occurs

Q3 – (b)

Isothermal process (Fig P - V , T - S diagram -2 marks; explanation- 2 marks)

- A process, in which temperature remains constant.

-There is no change in temperature.

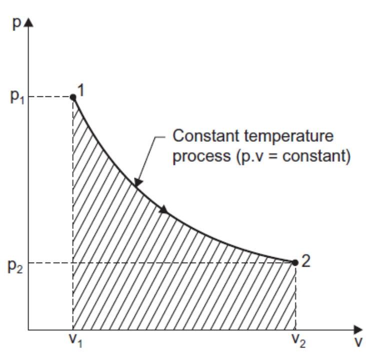
- There is no change in internal energy.

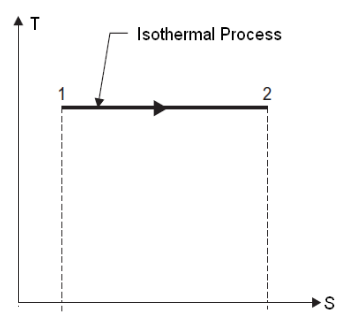
- There is no change in enthalpy.

- It follows Boyle's law, $\square \propto \frac{\square}{\square} = \square\square\square\square\square\square\square\square$

PV = Constant

$P_1 V_1 = P_2 V_2 = C$





Q3 – (c)

Steam boilers are classified mainly as follows. (Any four) 1 mark each.

i) Depending upon relative position of water and fuel gases.

a) Fire tube boilers.

b) Water tube boilers

ii) Depending upon position of axis of boilers.

a) Vertical boilers.

b) Horizontal boilers

iii) Depending upon position of furnace.
a) Internally fires boilers.
b) Externally fires boilers.

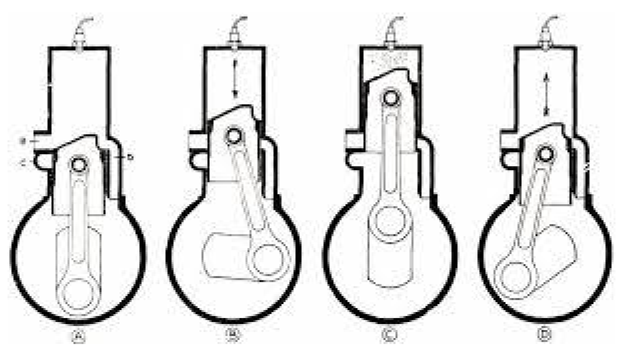
iv) Depending upon application.
a) Stationary boilers.
b) Portable boilers.
c) Locomotive boilers.
d) Marine boilers.

v) Depending upon circulation of boilers.
a) Natural circulation boilers.
b) Forced circulation boilers.

vi) Depending upon pressure of steam generated.
a) Low pressure boilers.
b) High pressure boilers.
vii) Depending upon nature of draught employed.
a) Natural or chimney draught
b) Artificial draught.

Q3 – (d) (Fig. 2 Marks and explanation 2 Marks)

Working of Two stroke Petrol Engine



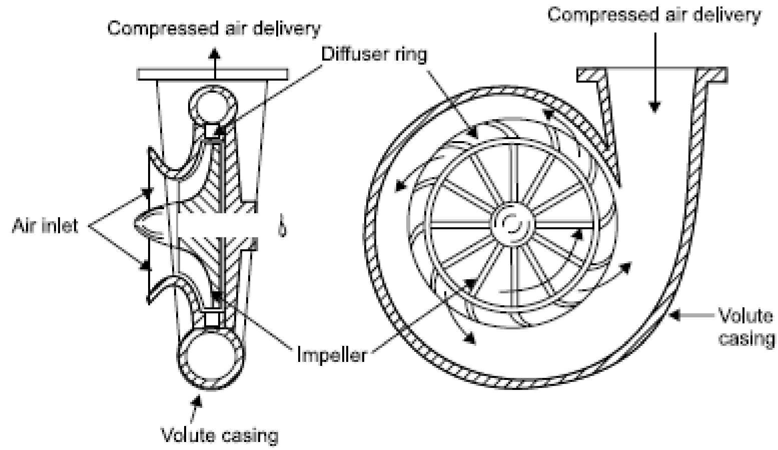
When the piston moves from TDC to BDC i.e. downwards after expansion of gases , the piston uncovers the exhaust port. The burnt gases start going out of the cylinder. Simultaneously the slightly compressed charge in the crank case is forced into the cylinder through transfer port. The deflector on the piston crown deflects this charge and the fresh charge moves in the upward direction. This fresh charge pushes the burnt gases out the cylinder. During this process some fresh charge may also leave the cylinder through exhaust.

When the piston moves upwards from BDC to TDC, transfer port and exhaust ports are closed. Compression of charge, present in the cylinder takes place. During this motion the inlet valve open and fresh charge enters the crankcase. When the piston reaches the TDC, compression process is completed.

After compression, spark plug generates spark and ignition of fuel takes place. Rapid rise in pressure and temperature takes place at constant volume. At this stage both transfer port and exhaust port are closed. Expansion of burnt gases takes place as the piston moves downward from TDC to BDC. The gases push the piston with great force and power is obtained during this process. Simultaneously, slight compression of fresh charge present in crank case takes place.

Q3 – (e) (Working Principle 02 marks, Sketch 02 marks)

CENTRIFUGAL COMPRESSOR:



Centrifugal compressor is a radial flow machine compressing the fluid due to the dynamic action of impeller. Centrifugal compressors have impeller mounted on driving shaft, diffuser and volute casing. Centrifugal compressors have air inlet at the centre of impeller. The portion of impeller in front of inlet passage is called impeller eye.

Impeller is a type of disc having radial blades mounted upon it. Compressor casing has a diffuser ring surrounding impeller and the air enters the impeller eye and leaves from impeller tip to enter diffuser ring. Volute casing surrounds the diffuser ring. Volute casing has cross section area increasing gradually up to the exit of compressor. These impellers of centrifugal compressors may also be of double sided type such that air can enter from two sides (both) of impeller.

Air enters the impeller eye axially and flows radially outwards after having entered compressor. Radial flow of air inside compressor is due to impeller (blades) rotating about its axis. These impeller blades impart momentum to the air entering, thereby rising its pressure and temperature. Subsequently the high pressure fluid leaving impeller enters the diffuser ring where the velocity of air is lowered with further increase in pressure of air. Thus in diffuser ring the kinetic energy of air is transformed into pressure head. High pressure air leaving diffuser is carried by volute casing to the exit of compressor. Due to increased cross section area of volute casing some velocity is further reduced causing rise in its pressure, although this is very small. Total pressure rise in compressor may be due to 'impeller action' and 'diffuser action' both. Generally, about half of total pressure rise is available in impeller and remaining half in diffuser.

Centrifugal compressors are used in aircrafts, blowers, superchargers, etc. where large quantity of air is to be supplied at smaller pressure ratios. Generally, pressure ratio up to 4 is achieved in single stage centrifugal compressors while in multistage compressors the pressure ratio up to 12 can be achieved. These compressors run at speed of 20,000–30,000 rpm.

Q3 – (f) (Two marks for components and two for applications)

The main components of VCC are -

1) **Compressor:** Compressor is the most important component of VCC refrigeration system and is considered being the heart of the system. The function of compressor is to compress the low pressure refrigerant from evaporator to condenser pressure at a temperature more than saturation temperature corresponding to condenser pressure.
2) **Condenser:** condenser is heat rejection component in vapour compression system. Function of condenser in refrigeration system is to superheat and condense the compressor discharged vapour and frequently to sub-cool the liquid with minimum pressure drop.
3) **Expansion Device:** It is the pressure reducing component in vapour compression system. Its function is to reduce pressure of refrigerant from condenser pressure to evaporator pressure by throttling and to control mass flow rate of refrigerant entering in evaporator as per load on evaporator.
4) **Evaporator:** It is a component in which refrigerating effect is obtained. Refrigerating effect is produced in evaporator. The liquid at low pressure enters in evaporator, by absorbing heat it converts into vapours. These vapours are drawn in suction line of compressor.

Applications of V.C.C.

1) Water cooler
2) Domestic refrigerator
3) Ice plant
4) Cold storage
5) Air Conditioner

Q4 – (a)

Q.4 (a)

Temp. of Source $T_1 = 30 + 273 = 303^\circ K$

Temp. of Sink $T_2 = -15 + 273 = 258^\circ K$

$$\therefore \; COP_{Ref} = \frac{T_2}{T_1 - T_2} = \frac{258}{303 - 258} = 5.733$$

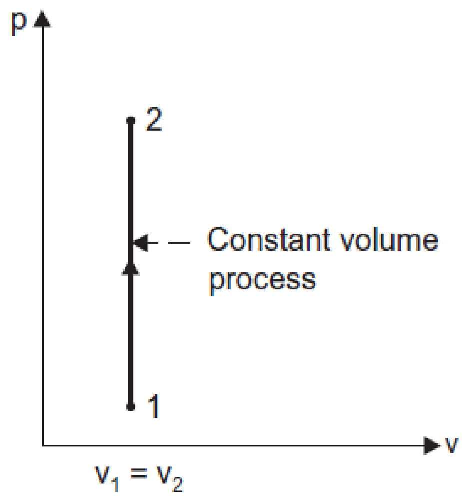
$$COP_{Ref} = \frac{R.E.}{\text{Compressor work}} = 5.733$$

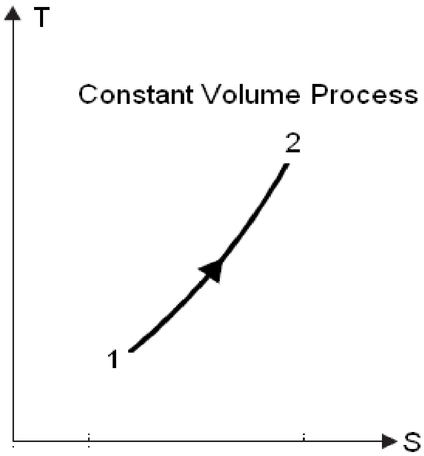
$$\text{Compressor work} = \frac{1.75}{5.733} = 0.305 \text{ Kw}$$

i.e. Power required $= 0.305$ Kw

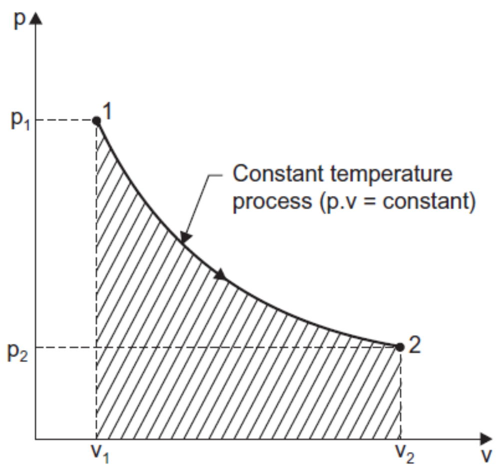
Q4 – (b) (Two marks for each process)

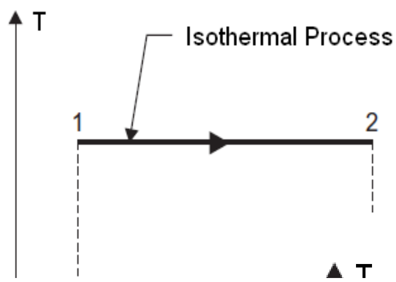
Gas processes on P-V and T-S diagram:
Isochoric process



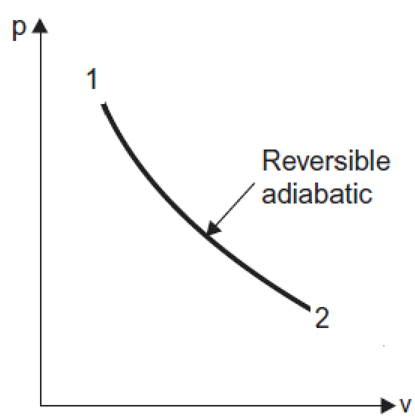


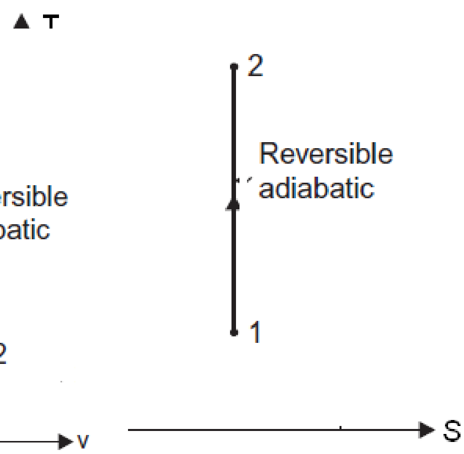
Isothermal process



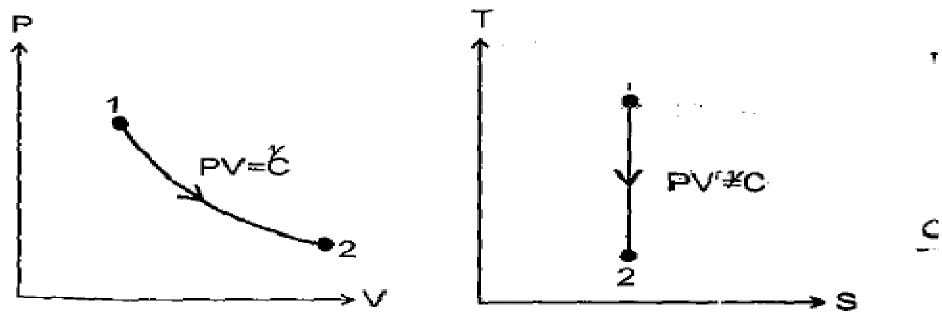


Adiabatic process





Polytropic Process :



Q4 – (c) (fig. – 4 marks, explanation -4 marks)

Impulse turbine

Construction of Impulse turbine.

1. The impulse turbine consists of one set of nozzle, which is followed by one set of moving blades as shown as in figure.
2. In this type of turbine, power is developed by the impulsive force.
3. The high velocity steam jets are obtained by expansion of steam in the stationary nozzle only
4. Steam then passes at high velocity through moving blade with no drop in pressure but a gradual reduction in velocity.
5. Thus in pure impulse turbine the high velocity jet having nozzle strikes on the blades mounted on the wheel attached to the shaft.
6. These blades changes the direction of steam and hence momentum of the jet of steam, which rotates the shaft.
7. The nozzle axis is inclined to an angle to the tangent of the rotor.

The high velocity steam jet are obtained by complete expansion of steam in the stationary nozzles fitted in diaphragm then this high velocity steam passes through moving blades with no drop in pressure but gradual reduction in velocity.

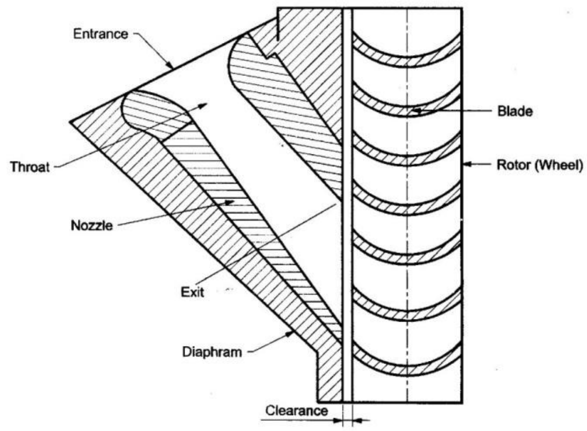


Fig: Simple impulse turbine

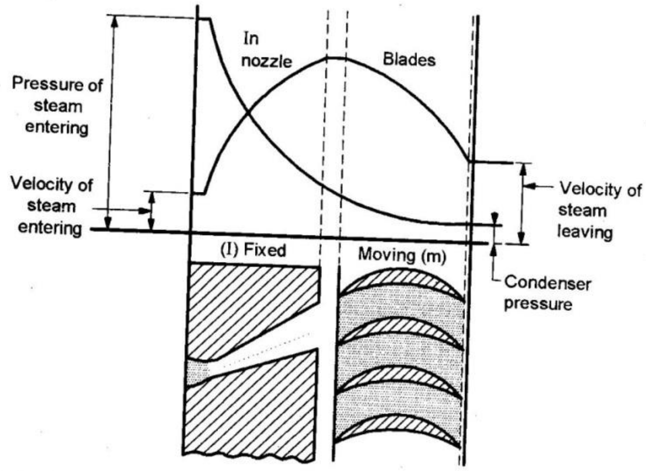


Fig: Variation of pressure and velocity

Q5 – (a) (Four marks for explanation and four for types)

Fuel cell : Fuel cells are electrochemical devices that convert a fuel chemical energy directly to electrical energy without an intermediate combustion or thermal cycle.

With no internal moving parts fuel cells operate similar to batteries. An important difference is that batteries store energy while fuel cells produce electricity continuously as along as fuel and air are supplied. Fuel cells virtually emit no pollution as the waste exhaust is simply water vapour and heat.

Fuel cells are classified as follows:

1) **On the basis of type of electrolyte**

   i) Phosphoric acid fuel cell (PAFC)

   ii) Alkaline fuel cell (AFC)

   iii) Molten Carbon fuel cell (MCFC)

   iv) Solid oxide fuel cell (SOFC)

v) Polymer membrane Fuel cell (PEMFC)

2) On the basis of type of fuel and oxidant

i) Hydrogen-oxygen fuel cell

ii) Hydrogen rich gas air fuel cell

iii) Ammonia air fuel cell

iv) Synthesis gas air fuel cell

v) Hydrogen air fuel cell

3) On the basis of operating temperature

i) Low temperature fuel cell (Below 150 ^{o} C)

ii) Medium temperature fuel cell (150 ^{o} C – 250 ^{o} C)

iii) High temperature fuel cell (250 ^{o} C – 800 ^{o} C)

iv) Very high temperature fuel cell (800^{o} C – 1100 ^{o} C)

Q5 – (b) (Two marks for statements each and four marks for types)

Second law of thermodynamics:

Kelvin-Planck statement of second law of thermodynamics: "It is impossible for a device operating in a cycle to produce net work while exchanging heat with bodies at single fixed temperature".

Clausius statement of second law of thermodynamics: "It is impossible to have a device that while operating in a cycle produces no effect other than transfer of heat from a body at low temperature to a body at higher temperature."

Types of energy :

a) Stored Energy

1) Mechanical energy

2) Electrical energy

3) Chemical energy

4) Magnetic energy

5) Internal energy

6) Potential energy

7) Kinetic energy

b) Energy in transition

1) Heat

2) work

Q5 – (c) (Four marks for classification and two for figure and two for explanation)

Air conditioning systems are classified as

1) Classification as to major function-

i) Comfort air-conditioning - air conditioning in hotels, homes, offices etc.

ii) Commercial air-conditioning- air conditioning for malls, super market etc iii) Industrial air-conditioning – air conditioning for processing, laboratories etc

2) Classification as to season of the year-

i) Summer air-conditioning - These system control all the four atmospheric conditions for summer comfort.

ii) Winter air-conditioning – This system is designed for comfort in winter. iii) Year round air-conditioning – These system consists of heating and cooling equipments with automatic control to produce comfortable condition throughout the year

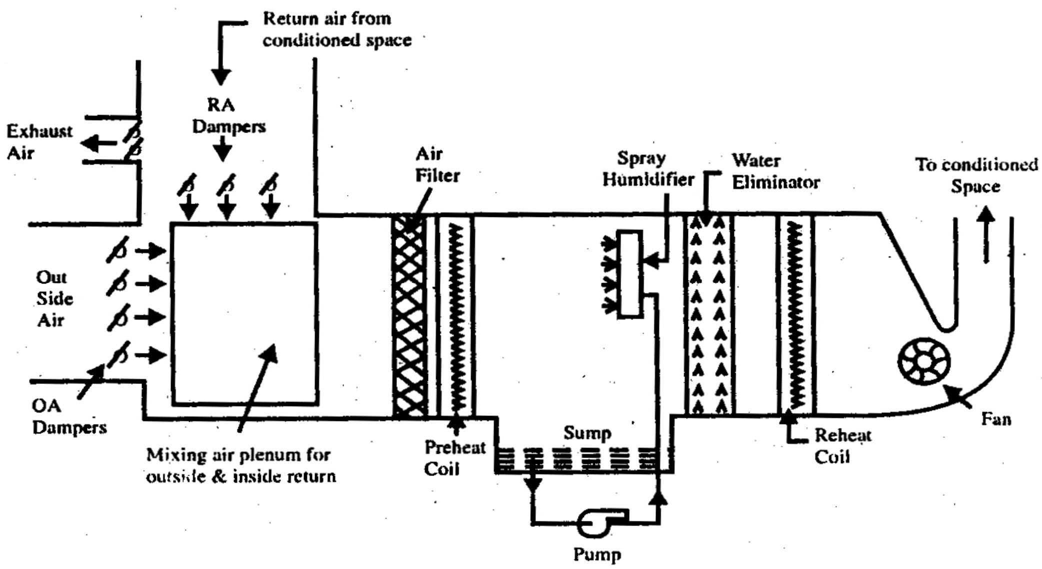
3) Classification as to Equipment Arrangement-

i) Unitary system

ii) Central system

Summer air conditioning system

Summer air conditioning system is used to provide human comfort in summer season. In summer season outdoor temperature is high and occupant feel comfortable at relatively low temperature. Air is passed over cooling coil where it reduces its temperature but relative humidity exceeds human comfort range. The air is passed over heating coil which restores humidify with in comfort zone and observe slight increase in temperature. Thus the major problem in summer air-conditioning is to cool air and remove excess moisture from it.



Q6 – (a) i)

Irreversibility – The actual work which a system does is always less than the idealized reversible work, and the difference between the two is called the irreversibility of the process.

Thus, Irreversibility = $W_{max} - W$

Q6 – (a) ii) Enthalpy : It is total heat content of the system. It is also defined as energy which is the algebraic sum of internal energy and flow work. **$H = U + pV$**

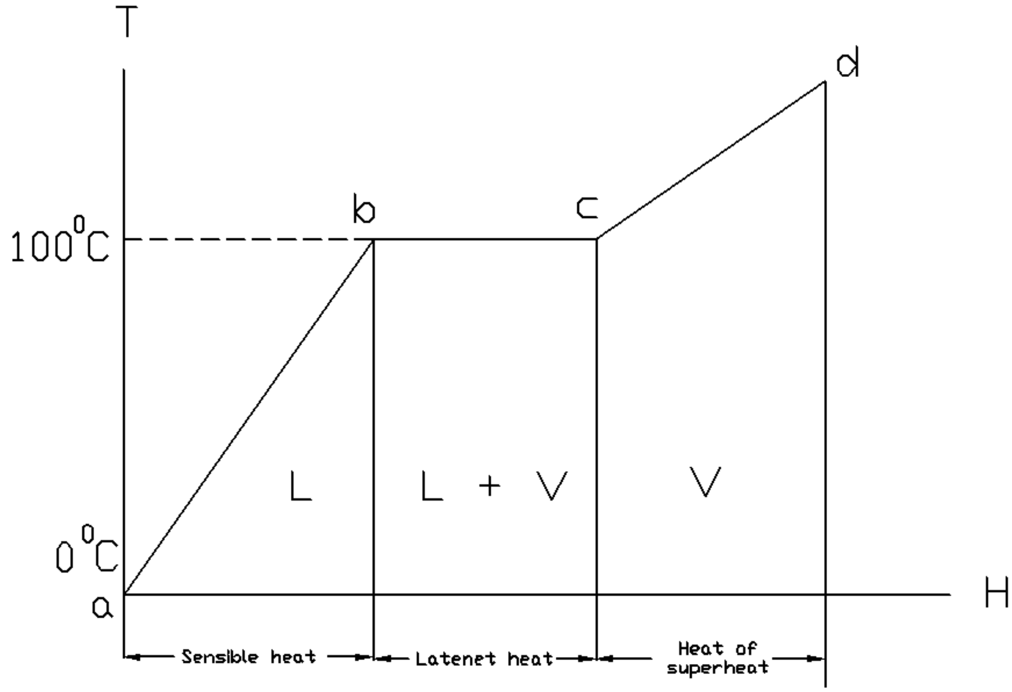
Q6 – (b) In general specific heat gives us an idea of the amount of heat we need to provide to a system in order to bring about a unit rise in the temperature of the system. It's value may vary depending on the process you are providing this energy. Hence we have two values of specific heats namely C_v and C_p

C_v for a gas is the change in internal energy (U) of a system with respect to change in temperature at a fixed volume of the system. Whereas C_p for a gas is the change in enthalpy (H) of the system with respect to change temperature at a fixed pressure of a system.

But since liquids and solids can practically assumed to be incompressible, C_v and C_p for them have almost same values and hence only a single value of specific heat is used for them.

Q6 – (c) (Explanation – 3 Marks Fig.- 1 Mark)

Figure shows different phases of steam formation from one kg of water at 0^o C under constant pressure processes. The steam formation process starting point is a. From a to b it is sensible heating process where water temperature is raised to 100 ^{o} C . From b to c 100 ^{0} C water is converted into 100 ^{o} c saturated steam. From c to d, the steam is superheated. In this case amount of heat required is known as heat of superheat or superheat enthalpy.



Q6 – (d) (Any four) 1/2 mark each)

Classification of I.C engine:

i) According to thermodynamic cycle :
Otto cycle , Diesel cycle , Dual cycle.

ii) According to cylinder arrangement

V-type engine, Radial engine. Inline engine

iii) According to fuel used

Petrol engine , Diesel engine , Gas engine

iv) According to method of cooling

Air cooled engine, Water cooled engine.

v) According to the number of strokes per cycle –

Two stoke engine, four stroke engine

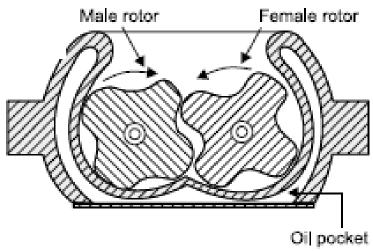
vi) According to number of cylinder used –

Single cylinder engine, multi cylinder engine

viii) According to the speed of the engine –

Slow speed engine, medium speed engine and high speed engine

Q6 – (e) (Sketch 02 marks, Working 02 marks)



Screw type compressor: Screw type compressor is very much similar to roots blower. These may have two spiral lobed rotors, out of which one may be called male rotor having3–4 lobes and other female rotor having 4–6 lobes which intermesh with small clearance. Meshing is such that lobes jutting out of male rotor get placed in matching hollow portion in female rotors. Initially, before this intermeshing the hollows remain filled with gaseous fluid at inlet port. As rotation begins the surface in contact move parallel to the axis of rotors toward the outlet end gradually compressing the fluid till the trapped volume reaches up to outlet port for getting discharged out at designed pressure. Since the number of lobes is different so the rotors operate at different speed.

Two rotors are brought into synchronization by the screw gears. Thrust upon rotors is taken care of by oil lubricated thrust bearings. These compressors are capable of handling gas flows ranging from 200 to 20000 m3/h under discharge pressures of 3 bar in single stage and up to 13 bar gauge in two stages. Even with increase in number of stages pressures up to 100 bar absolute have been obtained with stage pressure ratio of 2.Mechanical efficiency of these compressors is quite high and their isothermal efficiencies are even more than vane blowers and may be compared with centrifugal and axial compressors. But these are very noisy, sensitive to dust and fragile due to small clearances.

Q6 – (f) (03 marks for fig. with sketch-01 mark for labeling)

Window Air- conditioner