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Q: [C]ONST[ANT]-VOLUME PROCESS

[It] is the process during
where the volume of the system is kept constant.
total volume remains constant therefore no
[wo]r[k] is done during this process, or

$W = 0$

[Hen]ce the first law of thermodynamics for
[co]nst[ant]-volume process may be written as

$$\Delta E_{int} = Q.$$

If 'Q' heat is given to the system at
constant temperature, then its internal
energy increases and temperature increases.
Also we have

$$-\Delta E_{int} = -Q.$$

If 'Q' heat is rejected by the system
at constant volume, then its internal energy
decreases and temperature also decreases.

Q. Discuss cyclical process.

CYCLICAL PROCESS. A cyclical process
is that which consists of a sequence of
operations and finally it brings the system
back to its initial state. If the system
is back to its initial state, then the
net change in its internal energy must
be equal to zero. or $\Delta E_{int} = 0$.
Therefore the first law of thermodynamics
for cyclical process may be written as.

$0 = Q + W$ (cyclical Process)

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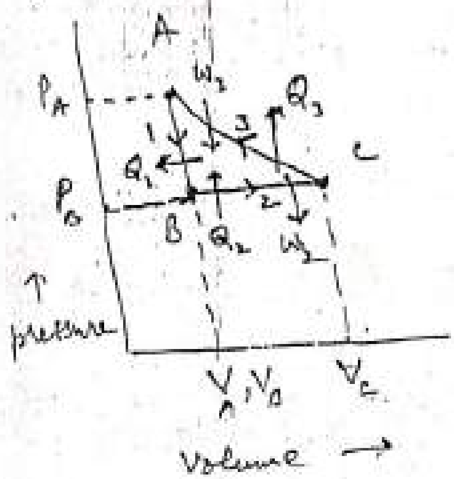
where 'Q' is the total heat and 'W' is the total work done during the cycle.

Let this cyclical process consists of three processes constant-volume process, constant-pressure process and isothermal process. After the completion of these three processes the system is back to its initial state, as shown in the fig.



i, CONSTANT-VOLUME PROCESS

Let the initial state of the system represented by the point A, where pressure and volume are P_A and V_A respectively. If 'Q_1' heat is rejected by the system and pressure is decreased from P_A to P_B at constant volume then represented by AB curve it is constant-volume process, during which no work is done; but the temperature and internal energy of the system decrease.

ii, CONSTANT-PRESSURE PROCESS

Now the pressure of the system, P_B is kept constant and 'Q_2' heat is given to the system so that its volume increases from V_B to V_C. The temperature and internal energy

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of the system also increase. This process is represented by BC curve. As volume of the system increase, therefore negative work is done during this process which is $-W_2$ and it is equal to the area under the curve BC.

iii, **ISOTHERMAL PROCESS**. During this process the gas is compressed slowly by increasing the pressure from P_C to P_A and constant temperature; so that 'Q_3' heat is rejected by the system. The volume of the system is decreased from V_C to V_A. This process is represented by CA curve, and the area under this curve is equal to the work done on the system which is positive W_3 (because volume decreases) therefore the net work done on the system during cyclic process is

$$W = W_3 - W_2$$ Here $W > 0$ because $W_3 > W_2$

Here 'W' is a positive value, but net heat is 'Q' is negative for the system (rejected by the system)

Therefore, for any cyclic process that is done in a counterclockwise direction, ~~positive~~ the net work done on the system is positive, while net heat is rejected by the system

or $W > 0$ and thus $Q < 0$ (negative)

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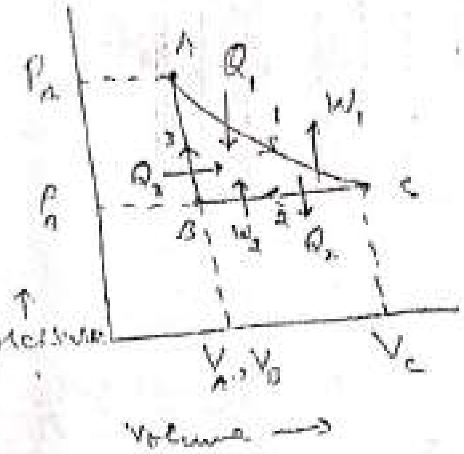
For any cyclic process that is done in a clockwise direction, as shown in the Fig. The net work done on the system is negative or $W < 0$, and the net heat for the system is positive or $Q > 0$.



Such cyclic process consists of isothermal, constant-pressure and constant-volume processes, as shown in the above Fig.

CONSTANT-PRESSURE PROCESS. It is the process during which the pressure of the system is kept constant. For this process the first law of thermodynamics is

$$\Delta E_{int} = Q + W$$ (The change in pressure is zero or $\Delta P = 0$)

or $$Q = \Delta E_{int} - W \quad \text{--- I}$$

If 'Q' heat is given to the system, at constant pressure, then the internal energy and temp of the system increases and volume of the system also increases, but the work done on the system will be negative. Equation I may also be written as $-Q = -\Delta E_{int} + W$

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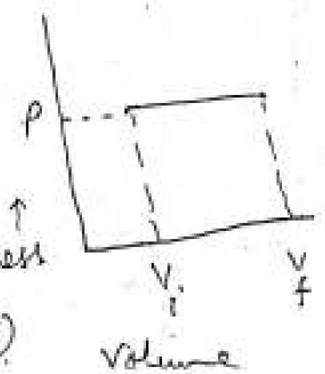
* 'Q' heat is rejected by the system at constant pressure then the internal energy and temperature of the system decrease, pressure and volume also decreases, but the work done on the system will be positive. This process is represented by the graph as shown in the fig.



Charle's law can be applied to this process.

$$\frac{V_i}{T_i} = \frac{V_f}{T_f} \quad \text{(constt press)}$$

Q. Discuss free expansion

FREE EXPANSION

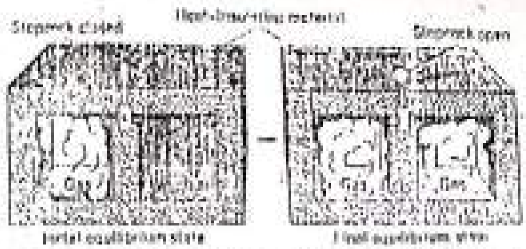


Figure 14 Free expansion. Opening the stopcock allows gas to flow from one side of the insulated container to the other. No work is done, and no heat is transferred to the environment.

Consider two small vessels of equal volumes connected with a stopcock, placed inside a big container which is well insulated from the environment. Initially first vessel is filled with a gas at certain temperature and pressure while the second vessel is evacuated. ~~If the stopcock is opened~~ If the stopcock is opened, then the gas expands into the second vessel also.

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the equal distribution
the gas attains an
equilibrium state again.
As the whole system is well insulated
from the environment, therefore there will be
no transfer of heat or $Q = 0$, also the
gas expands into an empty vessel without
raising any weight, therefore no work is done.
or

$$\boxed{W = 0}$$

Therefore during this free expansion we have

$$\boxed{Q = 0} \text{ and } \boxed{W = 0}$$

Hence the first law of thermodynamics
for this process may be written as

$$\boxed{\Delta E_{int} = 0}$$

It means that there will be no change
in the internal energy of an ideal
gas during free expansion. Hence the
temperature of an ideal gas must remain
constant. The initial state of the gas (when
all gas is in one vessel) and the final state of
the (when all gas has equally expanded in
two vessel), can be represented by the
points in PV diagram, but during
that interval of time, when the gas is
flowing from one vessel to the other,

... temperature and the pressure do not have the unique values, (but changing values) and we cannot plot this process on a PV diagram.
Only the initial equilibrium state and final equilibrium states can be represented by points in PV diagram.
The first law of thermodynamics cannot be apply to analyze this process, because the internal energy depends only on the initial and final points.

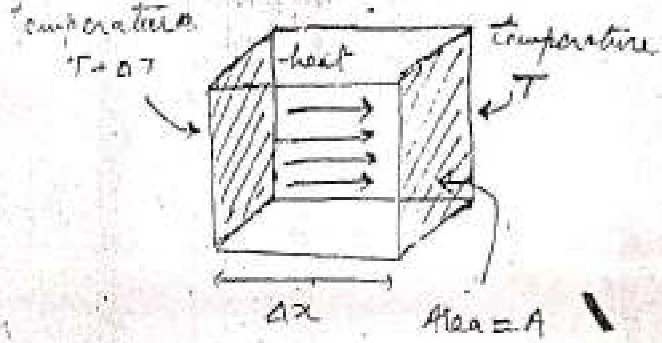
Q. What are the different modes / mechanisms of transfer heat ?, explain.

<u>Transfer of heat</u>. There are three modes or mechanisms of transfer of heat, conduction, convection and radiation.

<u>CONDUCTION OF HEAT</u>. Let only one end of the metal rod is heated, but after some time the other end of the rod also becomes hot. It means that the heat energy has ~~flown~~ transferred from one end to the other end. This mechanism of transfer of heat through the solid is known as conduction.

... is a mechanism in which heat energy is transferred from one part to the other part of the solid, from atom to atom, is called conduction. At the hot end of metal rod, the amplitude of vibration of the atoms is large and due to interaction between the adjacent atoms, these large vibrational amplitudes are passed from one end to the other end of the rod, which is actually the transfer of heat.

Let $(T+\Delta T)$ and T are the fixed values of the temperature at the two ends of a slab whose thickness is Δx, and 'A' is the area of cross-section, as shown in the fig.



Let 'Q' heat flows from the hot end to the cold end during a small interval of time Δt, then the rate of heat flow is

rate of flow
$$H = \frac{Q}{\Delta t}$$

This rate of heat flow is directly proportional to the difference of temperature $\boxed{\Delta T}$ and the area of cross-section 'A', but inversely proportional to the thickness or length 'Δx'.

Therefore

$$H \propto \frac{A \Delta T}{\Delta x}$$

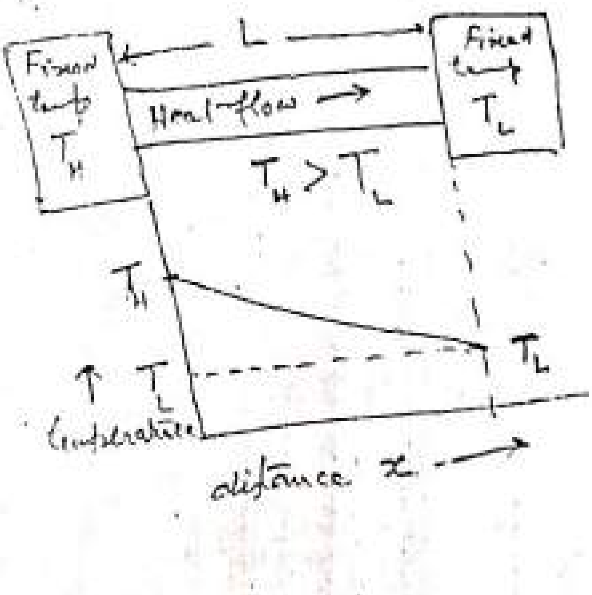
or

$$H = K \frac{A \Delta T}{\Delta x} = KA \frac{\Delta T}{\Delta x} \quad \text{---- I}$$

Here 'K' is the constant of proportionality and it is known as the thermal conductivity of the material of the slab, which has different values for different materials.

A substance with a large value of 'K' is a good heat conductor, for example any metal. A substance with a small value of 'K' is a poor conductor or good insulator of heat. Usually, most of the metals are good electrical conductors, because those have free electrons, but metals are also good thermal conductors. Hence the good electrical conductors are also good thermal conductors.

Consider a long rod of length L, and having uniform cross section 'A', whose one end is maintained at high temp T_H (fixed)



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... the other end at low temperature T_L (fixed), as shown in the Fig.

Then the heat energy flows from the hot to cold end at the constant rate, which is also called steady state situation. Therefore the rate of heat flow, H, (heat flowing per unit time) is given by

$$H = KA \frac{(T_H - T_L)}{L}$$

Here 'K' is the thermal conductivity of the rod (material). As every thing is constant on right hand side, therefore 'H' is also constant.

In choosing building materials, the thermal resistances of the materials are considered. The thermal resistance of a material is given by

$$R = \frac{L}{K}$$

where 'L' is the length or thickness and 'K' is the thermal conductivity of the material.

material of low conductivity is a good insulator and it has high thermal resistance or R-value. The materials of high thermal resistances are used in a building.

Now consider a slab which has infinitesimal (very small) thickness 'dx' and very small temperature difference 'dT'. The rate of flow of heat is given by

$$H = -KA\frac{dT}{dx}$$

Here the negative sign indicates that heat energy is flowing in the direction of decreasing $\frac{dT}{dx}$

Here $\frac{dT}{dx}$ is known as temperature gradient.

CONVECTION The second mechanism (or mode) of transfer of heat is Convection. The fluids (liquids and gases) are heated through the process known as Convection. In this process the molecules of fluid come to the place of high temp, and after getting heat move on the other side. Thus heat energy is transferred.

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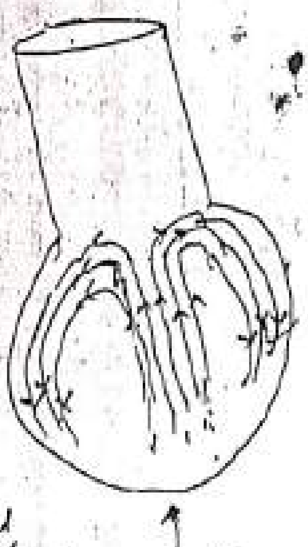
From one place to the other by the actual movement of the molecules.

Let a liquid (say water) is heated in a round bottom flask. It is observed that the water currents start flowing. At the mid region where heat energy is provided, water is heated, when its temperature increases then its density decreases. Therefore the water of low density rises up, while the cold water of high density falls down and comes to the place of high temp. Therefore the water currents are rising up in the middle, and falling down along the walls of the flask.



Atmospheric convection plays a fundamental role in determining the global climate patterns and in our daily weather variations.

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A huge amount of heat energy is also transferred within the oceans (by the process of convection) by means of hot water currents and cold-water currents). These are the examples of natural or free convection. Convection can also be forced, if a blower or pump is used to direct the heated or cooled fluid from one place to the other.

RADIATION The third mechanism (mode) for the transfer of heat is radiation. This is the process in which the heat energy is transferred from one place to the other in the form of electromagnetic waves like light waves. The electromagnetic waves move with constant velocity of $3 \times 10^8 \, ms^{-1}$ (velocity of light) and do not require any medium for their propagation. All the objects emit and absorb heat radiation simultaneously. If the temperature of an object is higher