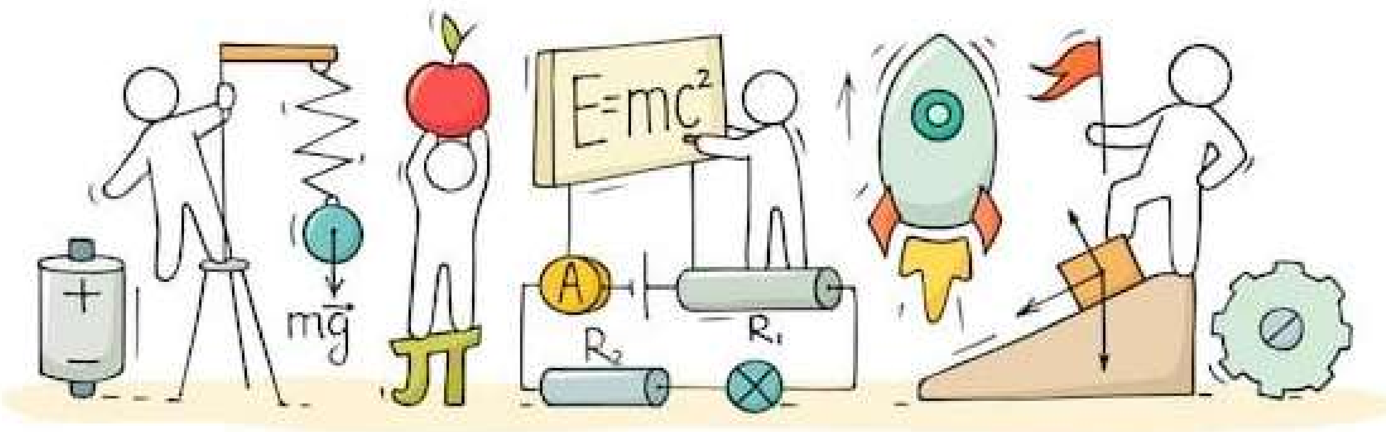
PHYSICS

Chapter 12: Thermodynamics



Thermodynamics

Top Formulae

- Equation of isothermal changes PV = constant or $P_2 V_2 = P_1 V_1$
- Equation of adiabatic changes

  i. $P_2 V_2^{\gamma} = P\ V_1$

  ii. $P^{1-\gamma} T_2^{\gamma} = P_1^{-\gamma} T^{\gamma}$

  iii. $T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$, where $\gamma = C_p / C_v$

- Work done by the gas in isothermal expansion

$$W = 2.3026\ RT \log_{10} \frac{V_2}{V_1}$$

$$W = 2.3026\ RT \log_{10} \frac{P_1}{P_2}$$

- Work done in adiabatic expansion

$$W = \frac{R}{(1-\gamma)}(T_2 - T\ )$$

- dQ = dU + dW

  Here, dW = P (dV), small amount of work done

  dQ = m L for change of state

  dQ = mc ΔT for rise in temperature

  dU = change in internal energy

- $$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T}$$

  Where T_1 = temperature of source, T_2 = temperature of sink; Q_1 is the amount of heat absorbed/cycle from the source, Q_2 is the amount of heat rejected/cycle to the sink.

- Useful work done/cycle $W = Q_1 - Q_2$

- Efficiency of Carnot engine is also given by $\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$

- Coefficient of performance of a refrigerator

  $$\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T}; W = Q_1 - Q_2$$

  where Q_2 is the amount of heat drawn/cycle from the sink (at T_2) and W is work done/cycle on the refrigerator. Q_1 is the amount of heat rejected/cycle to the source (air at room temperature T_1).

- $\beta = \frac{1 - \eta}{\eta}$

Top Concepts

- The nature of heat and its relationship to mechanical work was studied by Joule.
- Thermal equilibrium implies that systems are at the same temperature.
- Internal energy of a system is the sum of kinetic energies and potential energies of the molecular constituents of the system. It does not include the overall kinetic energy of the system.
- Equilibrium states of a thermodynamic system are described by state variables. The value of a state variable depends only on the particular state and not on the path used to arrive at that state.
- Examples of state variables are pressure (P), volume (V), temperature (T) and mass (m). Heat and work are not state variables.
- Zeroth law of thermodynamics: Two systems in thermal equilibrium with a third system are in thermal equilibrium with each other.
- The first law of thermodynamics is based on the principle of conservation of energy. It states that $\Delta U = \Delta Q - P\Delta V$
- The efficiency of a heat engine is defined as the ratio of the work done by the engine to the input heat.

  $$\eta = \frac{\text{Work done}}{\text{Input heat}} = \frac{W}{Q_H}$$

- If all the input heat is converted entirely into heat, then the engine would have an efficiency of 1.
- In a reversible process, both the system and its environment can be returned to their initial states.
- Spontaneous processes of nature are irreversible. The idealised reversible process is a quasi-static process with no dissipative factors such as friction, viscosity etc.
- A quasi-static process is an infinitely slow process such that the system remains in thermal and mechanical equilibrium with the surroundings throughout. In a quasi-static process, the pressure and temperature of the environment can differ from those of the system only infinitesimally.
- A heat engine is a device in which a system undergoes a cyclic process resulting in conversion of heat into work.
- The Carnot engine is a reversible engine operating between two temperatures T_1 (source) and T_2 (sink). The Carnot cycle consists of two isothermal processes connected by two adiabatic processes.
- The efficiency of the Carnot engine is independent of the working substance of the engine. It only depends on the temperatures of the hot and cold reservoirs.
- Efficiency of the Carnot engine is $\eta = 1 - T_C/T_H$ = 1 − (Temperature of cold reservoir/Temperature of hot reservoir).
- The efficiency of an engine is never more than that of a Carnot engine.
- Implications of the first law of thermodynamics:

  i. Heat lost by a hot body = heat gained by a cold body

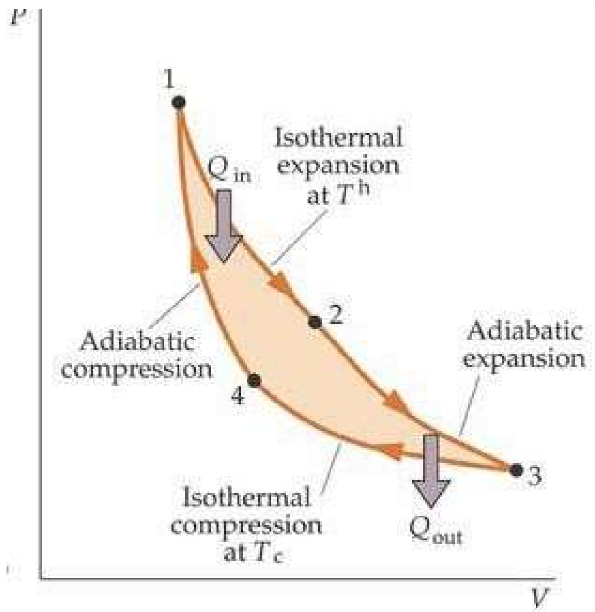
  ii. Heat can flow from cooler surroundings into a hotter body (e.g. coffee) to make it hotter.
- Kelvin's statement of the second law of thermodynamics:

  No heat engine can convert heat into work with 100% efficiency.
- Clausius statement: No process is possible whose sole result is the transfer of heat from a colder to a hotter body.
- Kelvin's statement: No process is possible whose sole result is the complete conversion of heat into work.

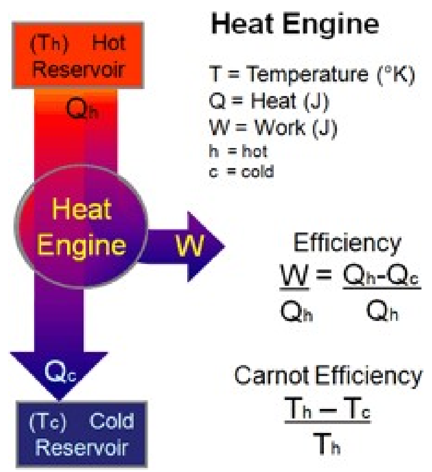
- The coefficient of performance of a refrigerator is $\alpha = Q_C/W$.
- A heat pump is called so because it pumps heat from the cold outdoors (cold reservoir) into the warm house (hot reservoir).
- When $Q > 0$, heat is added to the system. When $Q < 0$, heat is removed from the system. When $W > 0$, work is done by the system. When $W < 0$, work is done on the system.

Diagrams

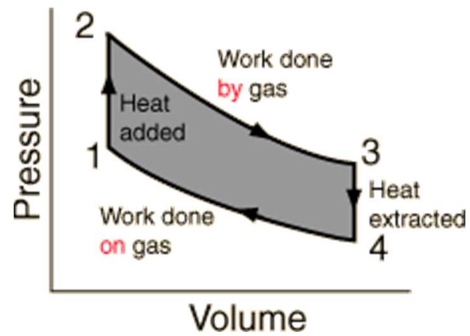
P–V curve for isothermal and adiabatic processes of an ideal gas



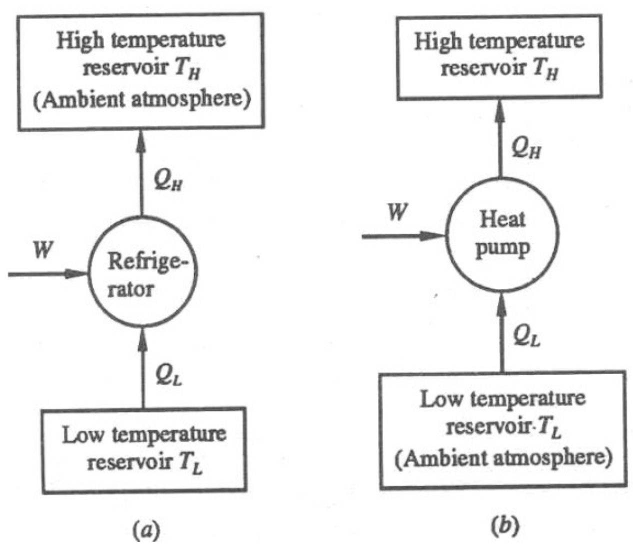
Heat engine



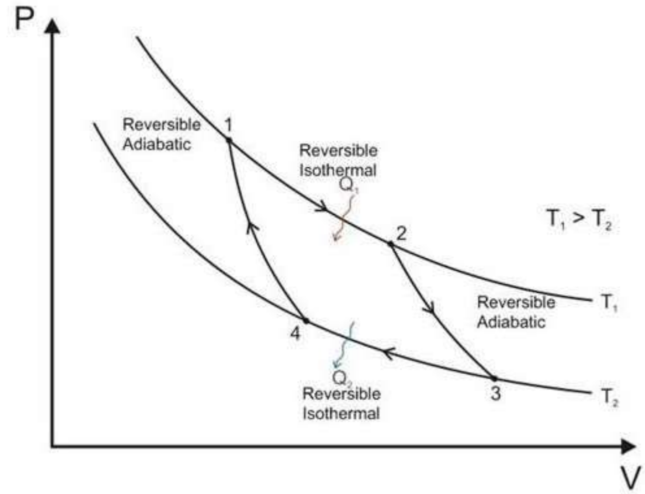
Work done by a heat engine



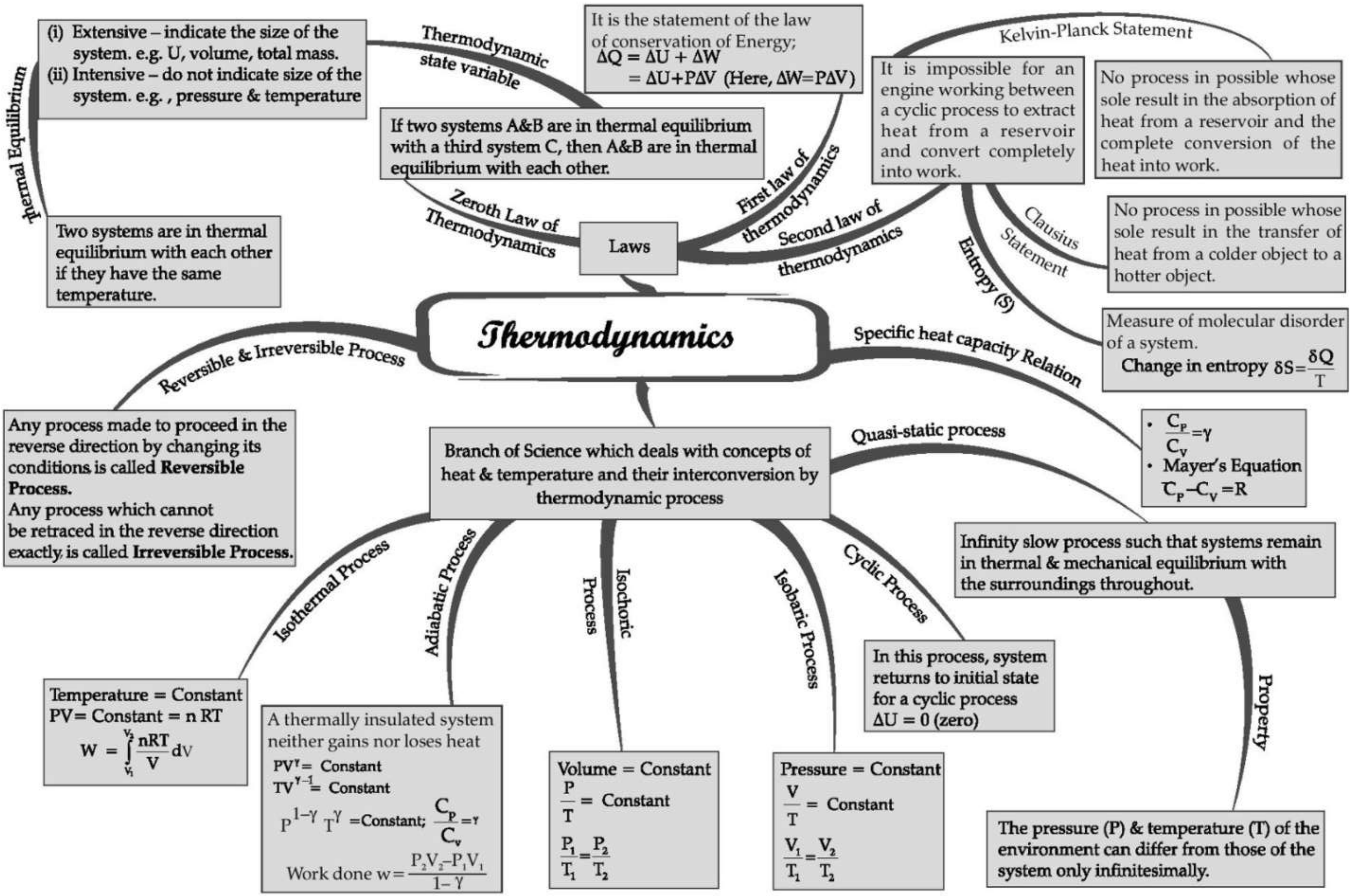
Refrigerator and heat pump



Carnot cycle for a heat engine with an ideal gas as a working substance



CHAPTER - 12 : THERMODYNAMICS



Important Questions

Multiple Choice questions-

1. A vessel contains a mixture of one mole of oxygen and two moles of nitrogen at 300 K. The ratio of the average rotational kinetic energy per O^2 to per N^2 molecule is

(a) 1 : 1

(b) 1 : 2

(c) 2 : 1

(d) depends on the moment of inertia of the two molecules

2.For a diatomic gas change in internal energy for a unit change in temperature for constant pressure and constant volume is U1 and U2 respectively. What is the ratio of U1 and U2?

(a) 5 : 3

(b) 3 : 5

(c) 1 : 1

(d) 5 : 7

3. An ideal gas heat engine operates in Carnot cycle between 227°C and 127°C. It absorbs 6 × 104 cal of heat at higher temperature. Amount of heat converted to work is:

(a) 2.4 × 104 cal

(b) 6 × 104 cal

(c) 1.2 × 104 cal

(d) 4.8 × 104 cal

4. Which of the following parameters dose not characterize the thermodynamic state of matter?

(a) work

(b) volume

(c) pressure

(d) temperature

5. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased, so as to increase its efficiency by 50% of original efficiency?

(a) 275 K

(b) 325 K

(c) 250 K

(d) 380 K

6. The translational kinetic energy of gas molecules at temperature T for one mole of a gas is

(a) (3/2) RT

(b) (9/2) RT

(c) (1/3) RT

(d) (5/2) RT

7. The temperature of reservoir of Carnots engine operating with an efficiency of 70% is 1000 kelvin. The temperature of its sink is

(a) 300 K

(b) 400 K

(c) 500 K

(d) 700 K

8. A gas is taken through a number of thermodynamic states. What happens to its specific heat?

(a) It is always constant.

(b) It increases.

(c) It decreases.

(d) It can have any value depending upon the process of heat absorbed or evolved.

9. Directions: The following has four choices out of which ONLY ONE is correct. A refrigerator with its power on, is kept in a closed room with its door open, then the temperature of the room will _________.

(a) rise

(b) fall

(c) remain the same

(d) depend on the area of the room

10. Directions: The following has four choices out of which ONLY ONE is correct. Which of the following is incorrect regarding the first law of thermodynamics? A. It is not applicable to any cyclic process B. It is a restatement of the principle of conservation of energy C. It introduces the concept of the internal energy D. It introduces the concept of the entropy

(a) A and D

(b) B and C

(c) C and A

(d) A and B

Very Short:

1. What type of process is Carnot's cycle?
2. Can the Carnot engine be realized in actual practice?
3. A refrigerator transfers heat from a cold body to a hot body. Does this not violate the second law of thermodynamics?
4. What is a heat pump?
5. What forbids the complete conversion of work into heat?
6. Does the internal energy of an ideal gas change in:

   (a) an isothermal process?

   (b) an adiabatic process?
7. What is the specific heat of a gas in an isothermal process and in an adiabatic process? Why?
8. Can the temperature of an isolated system change?
9. Can we increase the coefficient of performance of a refrigerator by increasing the amount of working substance?
10. The door of an operating refrigerator is kept open in a closed room. Will it make the room warm or cool?

Short Questions:

1. Kelvin and Clausius's statements of the Second law of thermodynamics are equivalent. Explain?
2. Two identical samples of gas are expanded so that the volume is increased to twice the initial volume. However, sample number 1 is expanded isothermally while sample number 2 is expanded adiabatically. In which sample is the pressure greater? Why?
3. No real engine can have an efficiency greater than that of a Carnot engine working between the same two temperatures. Why?
4. Explain why two isothermal curves cannot intersect each other?
5. What is the source of energy when gas does work when expands adiabatically?
6. State and explain the zeroth law of thermodynamics?
7. State and explain the first law of thermodynamics. What are the sign conventions?

8. Why cannot a ship use the internal energy of seawater to operate the engine?
9. A certain amount of work is done by the system in a process in which no heat is transferred to or from the system. What happens to the internal energy and the temperature of the system?
10. If an electric fan is switched on in a closed room, will the air of the room be cooled? Why?

Long Questions:

1. Discuss the Carnot cycle and give essential features of a Carnot engine.
2. Derive the expression for the work done during:

   (a) Isothermal process

   (b) Adiabatic process
3. A gas is suddenly compressed to 1/3 of its original volume. Calculate the rise in temperature, the original temperature being 300K and $\gamma = 1.5$.
4. A perfect Qarjiotreiigifae utilizes an ideal gas. The source temperature is 500K and since the temperature is 375 K. If the engine takes 600 Kcal per cycle from the source, compute:

   (a) the efficiency of The engine.

   (b) work done per cycle,

   (c) heat rejected to the sink per cycle.
5. A refrigerator has, to transfer an average of 263 J of heat per second from temperature – 10°C to 25°C. Calculate the average power consumed assuming ideal reversible cycle and no other losses.

Assertion Reason Questions:

1. **Directions:** Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

   (a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
   (b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
   (c) If assertion is true but reason is false.
   (d) If the assertion and reason both are false.

   Assertion: When a bottle of cold carbonated drink is opened, a slight fog forms around the opening.

Reason: Adiabatic expansion of the gas causes lowering of temperature and condensation of water vapours.

2. **Directions:** Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

   (a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
   (b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
   (c) If assertion is true but reason is false.
   (d) If the assertion and reason both are false.

   Assertion: In adiabatic compression, the internal energy and temperature of the system get decreased.
   Reason: The adiabatic compression is a slow process

✓ Answer Key:

Multiple Choice Answers-

1. Answer: (a) 1 : 1
2. Answer: (c) 1 : 1
3. Answer: (c) 1.2 × 104 cal
4. Answer: (a) work
5. Answer: (c) 250 K
6. Answer: (a) (3/2) RT
7. Answer: (a) 300 K
8. Answer: (d) It can have any value depending upon the process of heat absorbed or evolved.
9. Answer: (a) rise
10. Answer: (a) A and D

Very Short Answers:

1. Answer: Cyclic process.
2. Answer: No. It is an ideal heat engine.
3. Answer: No. This is because external work is being performed.
4. Answer: A heat pump is a device that uses mechanical work to remove heat.
5. Answer: The second law of thermodynamics.

6. Answer: (a) No.

   (b) Yes.

7. Answer: It is infinite in isothermal process because $\Delta T = 0 \left(C = \frac{\Delta Q}{m\Delta T}\right)$ and zero in an adiabatic process as $\Delta Q = 0$.

8. Yes, in an adiabatic process the temperature of an isolated system changes. It increases when the gas is compressed adiabatically.

9. Answer: No.

10. Answer: The room will be slightly warmed.

Short Questions Answers:

1. Answer: Suppose we have an engine that gives a continuous supply of work when it is cooled below the temperature of its surroundings.

   This is a violation of Kelvin's statement. Now if the work done by the engine is used to drive a dynamo which produces current and this current produces heat in a coil immersed in hot water, then we have produced a machine which causes the flow of heat from a cold body to the hot body without the help of an external agent. This is a violation of Clausius's statement. Hence both statements are equivalent.

2. Answer: Pressure is greater in sample number 1 as can be explained: For isothermal expansion.

   $P_1V_1 = P_2V_2$ for no. 1 sample

   Now $V_2 = 2V_1$

   $\therefore P_1V_1 = P_2 2V_1$

   or

   $P_2 = \frac{P_1}{2}$ ...(i)

   Now for adiabatic expansion (for sample 2)

   $P_1V_1^\gamma = P_2V_2^\gamma$

   Or

   $$P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = P_1\left(\frac{V_1}{2V_1}\right)^\gamma$$

   $$= \frac{P_1}{2^\gamma} \text{ ...(ii)}$$

∴ From (i) and (ii) we find that pressure is greater in sample 1 as $\gamma > 1$.

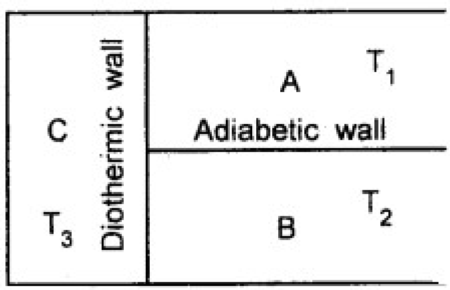
3. Answer: A Carnot engine is an ideal engine from the following points of view:

1. There is no friction between the walls of the cylinder and the piston.
2. The working substance is an ideal gas i.e. the gas molecules do not have molecular attraction and they are points in size.

However these conditions cannot be fulfilled in a real engine and hence no heat engine working between the same two temperatures can have an efficiency greater than that of a Carnot, engine.

4. Answer: If they intersect, then at the point of intersection, the volume and pressure of the gas will be the same at two different temperatures which is not possible.
5. Answer: During adiabatic expansion, the temperature and hence the internal energy of the gas decreases. Thus work is done by the gas at the cost of its internal energy.
6. Answer: It states that if two systems A and B are in thermal equilibrium with a third system C, then A and B must.be in thermal equilibrium with each other.

Explanation: The three systems are shown in the figure. Let T1, T2, T3 be the temperatures of A, B, and C respectively.



Systems A and C, B and C will exchange heat and after a certain time, they will attain thermal equilibrium separately.

i.e. $T_1 = T_3$ ....(1)

and $T_2 = T_3$ .... (2)

Thus from (1) and (2),

$T_1 = T_2$

i.e. A and B are now in thermal equilibrium with each other.

7. Answer: It states that if an amount of heat dQ is added to a system then a part of it may increase its internal energy by an amount dU and the remaining part may be used up as the external work dW done by the system i.e. mathematically,

$dQ = dU + dW$

$= dU + PdV$

Sign conventions:

1. Work done by a system is taken as positive while the work done on the system is taken as -ve.
2. The increase in the internal energy of the system is taken as positive while the decrease in the internal energy is taken as negative.
3. Heat added (gained) by a system is taken as positive and the heat lost by the system is taken as negative.

8. Answer: The heat engine can convert the internal energy of seawater if there is a sink at a temperature lower than the temperature of seawater. Since there is no such sink and hence a ship can't use the internal energy of seawater to operate the engine.
9. Answer: The temperature of the system decreases as the system is doing work and no heat transfer is allowed to or from the system. As the temperature of the system decreases, the internal energy of the system also decreases.
10. Answer: No. It will not be cooled, rather it will get heated because the speed of the air molecules will increase due to the motion of the fan. We feel cooler because of the evaporation of the sweat when the fan is switched on.

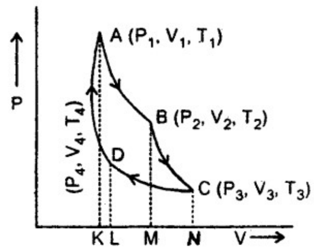
Long Questions Answers:

1. Answer: Carnot cycle: Heat engines essentially have
    1. a source of heat,
    2. a W0fkthg substance
    3. a sink (at a temperature lower than that source) and
    4. mechanical parts.

   Carnot designed an idea engine that operated in the reversible cycle. The cycle consisted of two isotherms and two adiabatic. The heat was taken in or rejected during isothermal expansion or contraction. The Carnot cycle thus consists of four steps (see fig.) Carnot took a perfect gas as the working substance enclosed in a cylinder with perfectly insulting walls fitted with an insulating piston but the bases of the cylinder were conducting

   (1) In the first step of the cycle let P_1, V_1, by the pressure of the gas. It is placed, in contact with the. source of heat at temperature T_1 i.e the cylinder is out on the source. As the gas expands isothermally it absorbs some amount of heat to keep the temperature constant (curve AB)

   The heat absorbed from the source Q_1 is equal to the work done W, in expanding the gas volume from V_1 to V_2 at temperature T_1 so that



$$Q_1 = W_1 = \int_{V_1}^{V_2} RT_1$$

In = Area ABMKA ….(1)

(2) The cylinder is put on insulating and gas is allowed to expand from V_2 to V_3 adiabatically. Its temperature falls from T_1 to T_2 and pressure becomes P_3 and P_2. The work done W is then.

$$W_1 = \int_{V_2}^{V_3} PdV = C_V(T_1 - T_2) = \text{Area BCNMB} \quad .... (2)$$

(3) In this part of the cycle the cylinder is put with its conducting base in contact with a sink as temperature T_2 and gas is compressed isothermally. It rejects Q_2 heat at constant temperature T_2, the work done on the gas is [pressure volume change to (P_4, V_4) from (P_3, V_3)].

$$Q_2 = W_3 = \int_{V_3}^{V_4} PdV = -RT \ln\frac{V_3}{V_2} = \text{Area CNLDC} \quad .... (3)$$

(4) In the last step of the cycle, the cylinder's base is again put on the insulating stand, and the gas is compressed adiabatically so that the system returns back to its original state at A i.e. from (P4, V4) to (P1, V1) at temperature T1 via curve DA. Now the work done on the gas is.

$$W_4 = \int_{V_4}^{V_1} PdV = C_V(T_2 - T_1) = -C_V(T_1 - T_2)$$

= Area DLKAD …. (4)

From equation (2) and (4), it is clear that $W_4 = W_2$

If W = net work done by the engine in one cycle, then

$W = W_1 + W_2 + (-W_3) + (-W_4)$

$= W_1 – W_3$ = Area ABCDA $= Q_1 – Q_2$ …..(5)

The efficiency of the Carnot engine (η): It is defined as the ratio of work done by the engine to the energy supplied to the engine in a cycle.

i.e $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

$= 1 - \frac{Q_2}{Q_1}$

Using equations (1) and (3)

$$\frac{Q_1}{Q_2} = \frac{RT_1 ln\frac{V_2}{V_1}}{RT_2 ln\frac{V_3}{V_4}} \quad ...(7)$$

Since B and C lie on the same adiabatic so

$T_1V_2^{\gamma-1}; = T_2V_3^{\gamma-1}$

or

$$\frac{T_1}{T_2} = \left(\frac{V_3}{V_2}\right)^{\gamma-1} \quad ....(8)$$

Also D and A lie on the same adiabatic so

$T_1V_1^{\gamma-1} = T_2V_4^{\gamma-1}$

or

$$\frac{T_1}{T_2} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \quad ....(9)$$

∴ from (8) and (9), we get

$$\left(\frac{V_3}{V_2}\right)^{\gamma} = \left(\frac{V_4}{V_1}\right)^{\gamma}$$

$$\ln\frac{V_3}{V_4} = \ln\frac{V_2}{V_1} \quad ...(10)$$

∴ from (7) and (10), we get

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}\frac{ln\left(\frac{V_2}{V_1}\right)}{ln\left(\frac{V_2}{V_1}\right)} = \frac{T_1}{T_2} \quad .... (11)$$

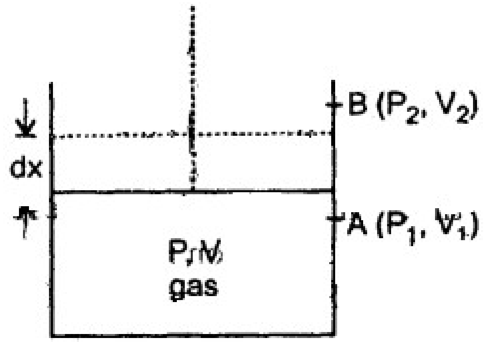
∴ from (6) and (11), we get

$$\eta = 1 - \frac{T_2}{T_1}$$

or $$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

1. The interesting aspect of η of Carnot engine is that it is independent of the nature of the working substance. But Carnot used an ideal gas operation which is not strictly followed by real gases or fuel
2. Theoretically, η can be 100%.
3. The efficiency of Carnot's ideal engine depends only on the temperature of the scarce and the sink.
4. The efficiency of any reversible engine working between the same two temperatures is the same.

2. Answer: Consider one mole of a perfect gas contained in a cylinder having conducting walls and fitted with a movable piston.



Let P, V be the pressure and volume of the gas corresponding to this state.

Let dx = distance by which piston moves outward at constant pressure P so that its volume increases by dV.

Let a = area of cross-section of the piston.

(a) If dW = work done in moving the piston by dx, then .

dW = force on piston × dx

= P a dx

= PdV ...(i)

Where dV = a dx = volume

Let the system goes from initial state $A(P_1, V_1)$ to final state $B(P_2, V_2)$

If W = total work done from A to B, then

$$W = \int_A^B dW = \int_{V_1}^{V_2} PdV \quad .... (ii)$$

Also we know that $PV = RT$ (n = 1 here)

$$P = \frac{RT}{V} \quad .... (iii)$$

∴ From (*ii*) and (*iii*), we get

$$W = RT \int_{V_1}^{V_2} \frac{1}{V} dV = RT[\log_e V]_{V_1}^{V_2}$$

$= RT (\log e V_2 – \log e V_1)$

$= RT \log_2 \frac{V_2}{V_1}$

$= 2.303\ RT \log_{10} \frac{V_2}{V_1}$

(b) From equation (ii) of case (a), we get

$$W = \int_{V_1}^{V_2} PdV \quad .... (ii)$$

We know that an adiabatic process is represented mathematically by the equation:

PV^{γ} = constant = K

Or

$$P = \frac{K}{V^{\gamma}} \ ... (iii)$$

∴ from (ii) and (iii), we get

$$W = \int_{V_1}^{V_2} KV^{-\gamma} dV = K\left[\frac{V^{1-\gamma}}{1-\gamma}\right]_{V_1}^{V_2}$$

$$= \frac{K}{1-\gamma}\left[V_2^{1-\gamma} - V_1^{1-\gamma}\right]$$

$$= \frac{1}{1-\gamma}\left[KV_1^{1-\gamma} - KV_2^{1-\gamma}\right]$$

$$= \frac{1}{1-\gamma}\left[P_1V_1^{\gamma}V_1^{1-\gamma} - P_2V_2^{\gamma}V_2^{1-\gamma}\right]$$

$$= \frac{1}{1-\gamma}\left[P_1V_1 - P_2V_2\right]$$

$$= \frac{1}{1-\gamma}\left[RT_1 - RT_2\right] \quad (\because PV = RT)$$

$$W = \frac{R}{\gamma-1}\left[T_1 - T_2\right].$$

3. Answer: Let V_1 = Initial volume

   V_2 = Final volume = $\frac{V_1}{3}$

   Or

   $\frac{V_1}{V_2} = 3$

   T_1 = 300K

   $T_2 - T_1$ = ?

   γ = 1.5

   We know that for an adiabatic change,

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

or

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

$$= 300\,(3)^{1.5-1} = 300\sqrt{3}$$

$$= 300 \times 1.732 = 519.6\text{ K}$$

$\therefore$ Rise in temperature $= T_2 - T_1$

$$= 519.6 - 300 = 219.6\text{ K}$$

4. Answer: Here, T_1 = 50.0 K

   T_2 = 375 k

   Q_1 = Heat absorbed per cycle

   = 600 K cal

   ∴ (a) Using tig relation,

$\eta = 1 - \frac{T_2}{T_1}$, we get

$\eta = \frac{T_1 - T_2}{T_1} = \frac{500-375}{500}$

$= \frac{125}{500} = 0.25$

$\eta\% = 0.25 \times 100 = 25\%$

(b) Let W = work done per cycle

∴ Using relation

$\eta = \frac{W}{Q_1}$, we get

$W = \eta Q_1$

$= 0.25 \times 600$ K cal

= 150 K cal

$= 150 \times 10^3 \times 4.2$ J

$= 6.3 \times 10^5$ J.

(c) Let Q_2 = heat rejected to the sink

∴ Using the relation

$W = Q_1 - Q_2$, we get

$Q_2 = Q_1 - W = 600 - 150 = 450$ K cal

5. Answer: Here, $T_1 = 25 + 273 = 298$ K

$T_2 = -10 + 273 = 263$ K

$Q_2 = 263$ Js^{-1}

we know that

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

$$\text{or} \quad Q_1 = \frac{T_1}{T_2} \times Q_2 = \frac{298}{263} \times 263$$

$= 298$ Js^{-1}

∴ Average power consumed $= Q_1 - Q_2$

$= (298 - 263)$ Js^{-1}

= 35W

Assertion Reason Answer:

1. If both assertion and reason are true and the reason is the correct explanation of the

assertion.

Explanation:

When a bottle of cold carbonated drink is opened. A slight fog forms around the opening. This is because of adiabatic expansion of gas causes lowering of temperature and condensation of water vapours.

2. If the assertion and reason both are false.

Explanation:

Adiabatic compression is a rapid action and both the internal energy and the temperature increases.

Case Study Questions-

1. Zeroth Law of Thermodynamics states that two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other. The Zeroth Law clearly suggests that when two systems *A* and *B,* are in thermal equilibrium, there must be a physical quantity that has the same value for both. This thermodynamic variable whose value is equal for two systems in thermal equilibrium is called temperature (*T*). Thus, if *A* and *B* are separately in equilibrium with C, *TA* = *TC* and *TB* = *TC*. This implies that *TA* = *TB* i.e. the systems A and B are also in thermal equilibrium. Zeroth Law of Thermodynamics leads to the concept of internal energy of a system. We know that every bulk system consists of a large number of molecules. Internal energy is simply the sum of the kinetic energies and potential energies of these molecules. A certain amount of heat is supplied to the system' or 'a certain amount of work was done by the system its energy changes.

i. Three thermodynamic systems are at temperature of 50^0 c .what can we say about them?
   a. Heat flows between them
   b. It obeys Zeroth Law of Thermodynamics
   c. Temperature of one system will increase and temperature of remaining two will decrease
   d. None of these

ii. Zeroth law of thermodynamics helped in the creation of which scale?
   a. Temperature
   b. Heat energy
   c. Pressure
   d. Internal energy

iii. State Zeroth Law of Thermodynamics

iv. Define Internal energy of system

2. Kelvin-Planck statement: No process is possible whose sole result is the absorption of heat from a reservoir and the complete conversion of the heat into work. Clausius statement: No process is possible whose sole result is the transfer of heat from a colder object to a hotter object. It can be proved that the two statements above are completely equivalent. A thermodynamic process is reversible if the process can be turned back such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe. a reversible process is an idealized motion. A process is reversible only if it is quasi-static (system in equilibrium with the surroundings at every stage) and there are no dissipative effects. For example, a quasi-static isothermal expansion of an ideal gas in a cylinder fitted with a frictionless movable piston is a reversible process. The free expansion of a gas is irreversible. The combustion reaction of a mixture of petrol and air ignited by a spark cannot be reversed. Cooking gas leaking from a gas cylinder in the kitchen diffuses to the entire room. The diffusion process will not spontaneously reverse and bring the gas back to the cylinder. The stirring of a liquid in thermal contact with a reservoir will convert the work done into heat, increasing the internal energy of the reservoir. The process cannot be reversed exactly; otherwise it would amount to conversion of heat entirely into work, violating the Second Law of Thermodynamics. Irreversibility is a rule rather an exception in nature.

i. The diffusion process is
   a. Reversible process
   b. Irreversible process

ii. A quasi-static isothermal expansion of an ideal gas in a cylinder fitted with a frictionless movable piston is
   a. Reversible process
   b. Irreversible process

iii. State Kelvin Planck statement.

iv. State Clausius statement.

v. Define reversible processes and irreversible processes of thermodynamics.

Case Study Answer-

1. Answer

i. (b) It obeys Zeroth Law of Thermodynamics

ii. (a) Temperature

iii. Zeroth Law of Thermodynamics states that two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other. i.e. when two systems *A* and *B,* are in thermal equilibrium individually with system C then these two systems are also in thermal equilibrium with each other.

iv. Internal energy is the sum of the kinetic energies and potential energies of all the molecules possesses by system.

2. Answer

i. (b) Irreversible process

ii. (a) Reversible process

iii. Kelvin-Planck statement states that We cannot construct any device like the heat engine that operates on a cycle, absorbs the heat energy, and completely transforms this energy into an equal amount of work. Some of the heat gets released into the atmosphere. Practically no device bears 100% thermal efficiency.

iv. According to clausius It is nearly impossible for heat to move by itself from a temperature that is lower in temperature to a reservoir that is at a higher temperature. That is we can say that the transfer of heat can only occur spontaneously from high temperature to temperature. i.e No process is possible whose sole result is the transfer of heat from a colder object to a hotter object without any external work provided to do it in short we cannot construct a refrigerator that can operate without any input work.

v. A thermodynamic process is said to be reversible if both the system and the surroundings return to their original states, with no other change anywhere else in the universe. On the other hand an irreversible process can be defined as a process in which the system and surrounding will not return to their original condition once the process is initiated.