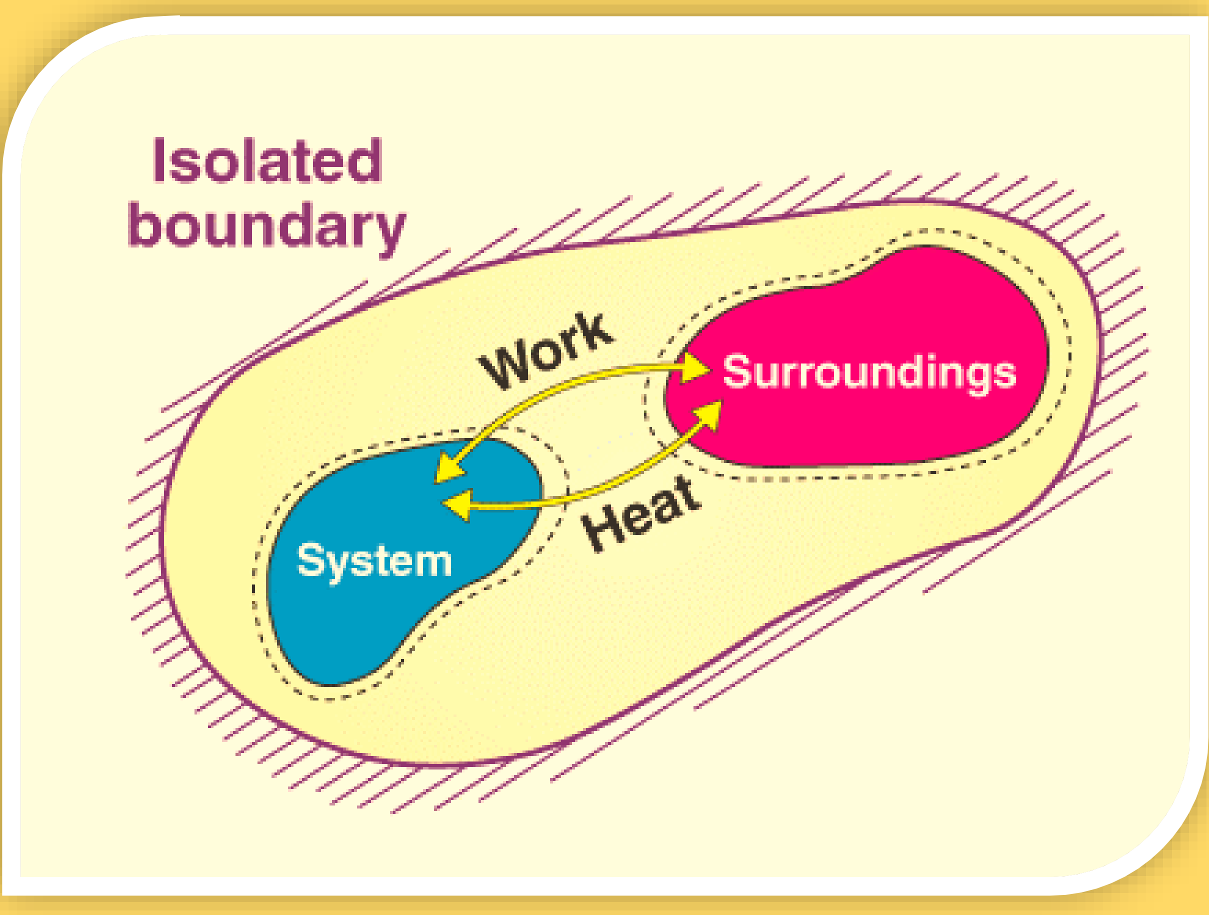
12. Thermodynamics



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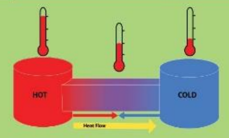
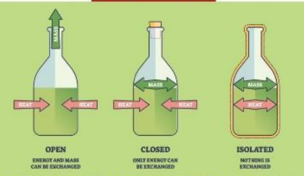
THERMODYNAMICS

Some Important terms



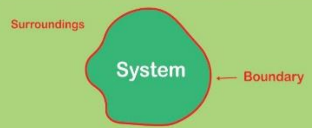
Branch of Physics that deals with concepts of heat and Temperature including inter – conversion of heat to another form.

System



A body of matter or radiation confined in spaced walls with definite permeabilities separated from surrounding.

Surrounding



Everything external to the system is known as surrounding.

Types of Systems

(1) In closed system, only energy transfer is possible rather than mass.
(2) In open system, both energy and mass transfer is possible.
(3) In isolated systems, both energy and mass transfer is not possible.

Equilibrium in Thermodynamics

(1) When the temperature difference between two bodies becomes zero then they are said to be in thermal Equilibrium.
(2) When all mechanical forces within the system are balanced to have zero acceleration system is in mechanical equilibrium.
(3) When no chemical reaction occur within reactants of system, then it is in chemical equilibrium.
(4) System is in thermodynamic equilibrium if all three equilibrium are attained.

ZEROTH LAW OF THERMODYNAMICES

If two bodies A and B are individually in thermal equilibrium with third body C, then A and B will also be in thermal equilibrium with each other.

FIRST LAW OF THERMODYNAMICS

If the energy (Q) supplied to system goes in partly to increase the internal energy of system (ΔU) and rest in work on environment, $Q = \Delta U + W$.

(1) Heat (Q) – Energy transfer to or from a thermodynamic system $= nC\Delta T$

(2) ΔU – Energy associated with internal configuration $= nC_v\Delta T$

(3) Area under P – V graph gives work done $W = \int_1^2 P.dV$

Point function and State function

(i) Function whose value depends on initial and final state of system is point function.
(ii) Function whose value depends on thermodynamic process is called path function.

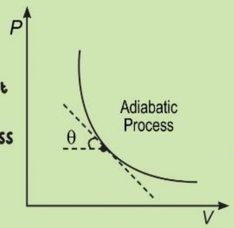
Adiabatic Process

(1) $W = \dfrac{P_1V_1 - P_2V_2}{\gamma - 1}$

γ – adiabatic constant

(2) Q = 0 for this process

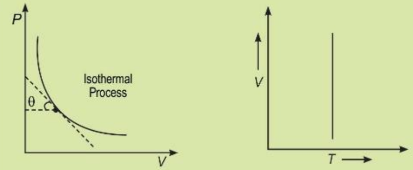
(3) $Q = \Delta U + W$; $W = \Delta U$



THERMODYNAMIC PROCESS

It is defined as change from one equilibrium microstate.

Isothermal Process

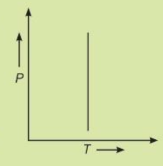


• Temperature, T = constant

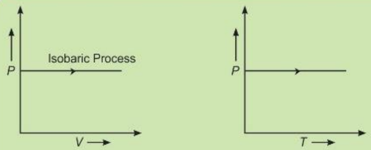
(1) $W = nRT\ln\left(\dfrac{V_2}{V_1}\right)$

(2) $W = 2.303\ nRT\log\left(\dfrac{V_2}{V_1}\right)$

(3) As, $Q = \Delta U$ for isothermal, $\Delta U = 0$, So, $Q = W$



Isobaric Process

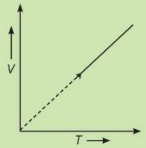


• Isobaric Process

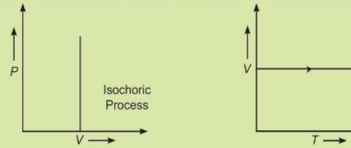
(1) $W = nR\Delta T = P\Delta V$

(2) $Q = \Delta U + W$

(3) Pressure, P = Constant.



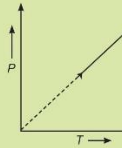
Isochoric Process



(1) Volume, V = Constant

(2) Work done, W = 0

(3) $Q = \Delta U + W$ So, $Q = \Delta U$



SECOND LAW OF THERMODYNAMICS

Kelvin – Planck's Statement:

"No process is passible, whose sale result is absorption of heat from reservoir and the complete conversion of heat into work"

Clausius Statement:

"No process is possible, whose sole result is the transfer of heat from a colder object to hotter object"

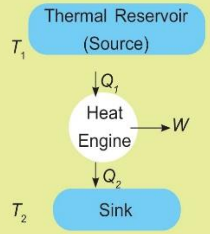
Heat Engine

• Engine that produces useful work.

• Pumps heat from source and transfer to sink.

$n = 1 - \dfrac{Q_2}{Q_1} = 1 - \dfrac{T_{sink}}{T_{source}}$

where source $> T_{sink}$

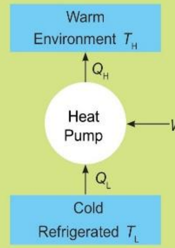


Heat Pump Refrigerator

• It operates in a cycle.

• It maintains body temperature lower than surrounding temperature by pumping out coefficient of performance

$= \dfrac{Q_H}{Q_H - Q_T} = \dfrac{T_H}{T_H - T_T}$



Carnot Engine

• Best known reversible cycle.

• Isothermal expansion

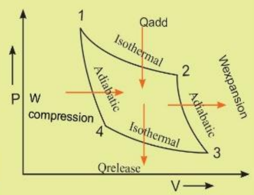
$W_1 = nRT\ \ln\left(\dfrac{V_2}{V_1}\right)$

• Adiabatic expansion, $W_2 = \dfrac{P_2V_2 - P_3V_3}{\gamma - 1}$

• Isothermal compression, $W_3 = -nRT\ \ln\left(\dfrac{V_4}{V_3}\right)$

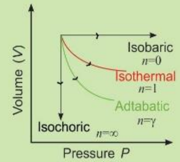
• Adiabatic compression $W_4 = \dfrac{-(P_4V_4 - P_1V_1)}{\gamma - 1}$

• $n = 1 - \dfrac{T_{Sink}}{T_{Source}}$



Polytropic Process

(1) PV^n = Const : n = polytropic index
(2) If n = 0, isobaric process
(3) If n = 1, isothermal process
(4) If n = γ, Adiabatic process
(5) If $n = \infty$, isochoric process



Thermodynamics

Thermodynamics: It is the macroscopic description of the interaction of a system with its environment, i.e., the surroundings. By interaction we mean the transformation of heat to other forms of energy and vice versa.

A thermodynamic system: It is an assembly of extremely large number of particles (atoms or molecules) in solid, liquid, gaseous, or a combination of two or more phases.

Environment: It is anything outside a thermodynamic system that has a direct effect on the system.

Thermodynamic (or state) variables: They are the parameters used to describe the state or condition of a thermodynamic system. They are also referred to as thermodynamic coordinates. State variables are **path independent**, i.e., they depend on the initial and final states of a system, but not how the change is brought about.

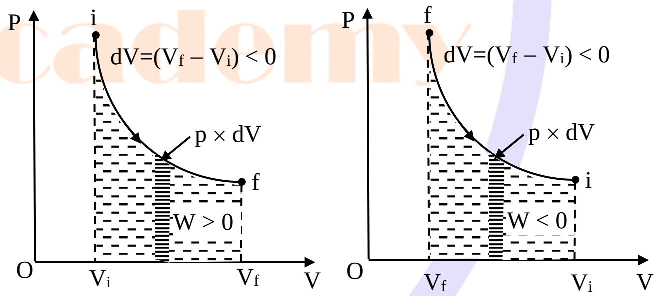
Example: (i) Composition (ii) Temperature (iii) Volume (iv) Pressure (v) Internal energy (vi) Entropy

Thermodynamic process: Whenever the state of a system changes, it is said to undergo a thermodynamic process. Common thermodynamic processes are (i) isothermal, (ii) isochoric (iii) isobaric (iv) adiabatic (v) cyclic processes.

☞ **Quasi-static** process is a process that occurs so slowly that the system proceeds through a series of equilibrium states during the change. It can be represented by a curve on a p-V, or a p-T, or a V-T diagram. All real processes are being regarded as quasi-static. Rapidly or violently changing process is not quasi-static.

Work: It is the energy exchanged between a system and its environment by means independent of temperature difference between them.

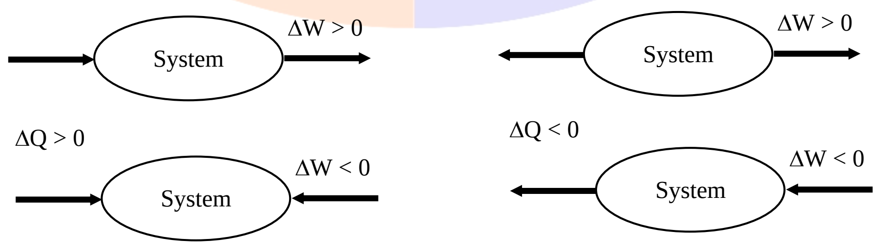
(a) Work done during a quasi-static process from initial state characteristised by (V_i, p_i, T_i) to a final state (V_f, p_f, T_f) is given by $W = \int_{V_i}^{V_f} p \times dV$



Indicator (pV) diagrams

To evaluate the integral, we must know how pressure varies during the process. Area under p.V curve gives the work done, i.e., if $V_f \neq V_i$

(b) **Sign convention:** (i) Heat entering a system is considered positive, i.e., $\Delta Q > 0$, while that leaving it is negative, i.e., $\Delta Q < 0$.

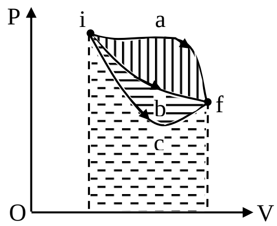


Symbolic representation of sign convention

(ii) Work done by a system, i.e., work leaving a system, is considered positive, i.e., $\Delta W > 0$, while that done on the system, i.e., work entering the system, is negative i.e., $\Delta W < 0$.

(c) **Dependence of work and heat on the process:** p-V diagram shows three processes a, b and c between states i and f of a system. It is obvious from the diagram that $Q_a \neq Q_b \neq Q_c$ and $W_a > W_b > W_c$

so, heat added and work done are path dependent.



(d) **Work done during various processes:**

(i) **Isochoric process (constant volume process):** No work is done since there is no change in volume.

$W_v = 0$ since $\Delta V = 0$

(ii) **Isobaric process (constant pressure process):** $W_p = nR[T_f - T_i]$

$n \rightarrow$ number of moles of an ideal gas

$T_i \rightarrow$ temperature of the initial state (i)

$T_f \rightarrow$ temperature of the final state (f)

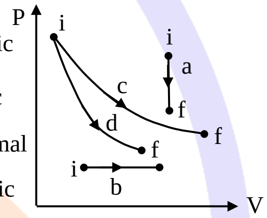
(iii) Isothermal process (constant temperature process):

a → isochoric

b → isobaric

c → isothermal

d → adiabatic



$$W_T = nRT \ \ln\left(\frac{V_f}{V_i}\right) = nRT \ \ln\left(\frac{p_i}{p_t}\right)$$

V_i, $V_f \rightarrow$ initial and final volumes of a system

p_i, $p_f \rightarrow$ initial and final pressure of the system at temp. T

$W_T > 0$ if $V_f > V_i$

$W_T < 0$ if $V_i > V_f$

(iv) Adiabatic process:

$$W_A = \frac{1}{1-\gamma}[p_f V_f - p_i V_i] = \frac{nR(T_f - T_i)}{1-\gamma}$$

$W_A < 0$ if $V_f < V_i$ (sudden compression)

$W_A > 0$ if $V_f > V_i$ (sudden expansion)

The first law of thermodynamics

Experiments show that the quantity (Q – W) is a constant for all processes for the given states. The quantity (Q – W) must represent some intrinsic property of the system, called its internal energy. This experimental fact leads to the first law of thermodynamics.

The first law of thermodynamics states that the net energy transferred equals the change in the internal energy of a system undergoing a process.

$$\Delta E_{int} = E_{f_{int}} - E_{f_{int}} = Q - W$$

where i indicates for initial state and f final state of the system.

When the energy transfers are small, $\Delta E_{int} = \Delta Q - \Delta W$

☞

- The first law of thermodynamics is an extension of the principle of conservation energy to systems that are not isolated. In such cases, energy may be transferred into or out of the system as either work or heat.
- **Internal energy** is the sum of the molecular kinetic energy, molecular potential energy and other kinds of molecular energy viewed from a reference frame at rest with respect to the system.
- Internal energy is associated with the random translational, rotational and vibrational motion

of the particles that make up the system.

- Internal energy also includes other kinds of energy like intermolecular potential energy together with nuclear, atomic and molecular binding energy.
- Internal energy does not includes kinetic energy of the molecules due to translation, rotation, or vibration of the whole or part of the system, and potential energy due to interactions of the molecules of the system with something outside the system.
- Internal energy of a monatomic gas is associated with the translational kinetic energy of its atoms. $E_{int} = 3nRT/2$
- For diatomic and polyatomic molecules, internal energy includes other forms of energy as well.

Application of the first law of thermodynamics

(a) **Isochoric process (constant volume process → change in volume ΔV = 0):** W = 0; since ΔV = 0, ΔE_{int} = Q. So, heat transferred to a system at constant volume goes to increase the internal energy (and temperature) of the system.

(b) **Isobaric process (constant pressure process):** Boiling of water at atmospheric pressure is an example. Phase change occurs at constant temperature and pressure from liquid to vapour.

$W = p(V_f - V_i)$; $Q = mL_v$; $\Delta E_{int} = Q - W = mL_v - p(V_f - V_i)$

m → mass of water, L_v → latent heat of vapourisation.

(c) **Isothermal process:** $\Delta E_{int} = 0$ since $\Delta T = 0$; W = Q

Heat transferred to a system at constant temperature appears as work against the surroundings.

(d) **Adiabatic process:** $\Delta E_{int} = -W$ since Q = 0

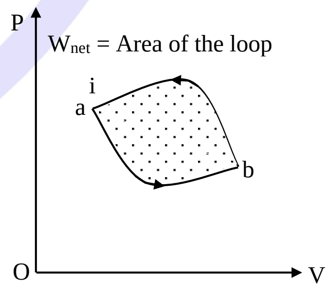
Work is done at the expense of internal energy. When a system undergoes an adiabatic expansion W > 0. When the system undergoes an adiabatic compression, W < 0.

(e) **Melting process:** The change of phase occurs at constant temperature and pressure. Slight change in volume can be neglected.

W = 0 since $\Delta V \approx 0$; $\Delta E_{int} = Q = mL_f$

m → mass of the solid, L_f → latent heat of fusion of the solid. So, the **internal energy increases**, but the **temperature does not**. It implies that the internal potential energy increases, not the internal kinetic energy.

(f) **Cyclic process:** It is a process in which a system returns to its initial state after a certain interchange of heat and work. No intrinsic property (including its internal energy) can possibly change.

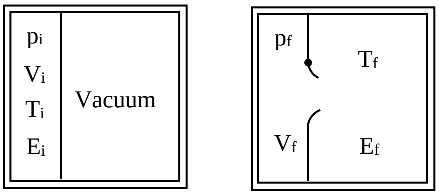


Q = W since $\Delta E_{int} = 0$

Thus, the net work during cyclic process equals the net heat transferred.

(g) **Free expansion:** Consider an ideal gas in a two chambered container having an adiabatic membrane separating the chambers. The other chamber is evacuated. If the membrane breaks spontaneously, the gas expands freely to occupy the entire container. Such a process is called free expansion. In free expansion, Q = 0 and W = 0 because no heat is transferred and no work is done since the gas rushes into a vacuum.

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



- A free expansion is essentially an adiabatic process.
- A free expansion cannot be described by an indicator diagram because the gas is not in thermal equilibrium during the process.
- Initial and final states of a freely expanding gas can be shown on the indicator diagram once it attains thermal equilibrium.

(h) Limitation of the first law

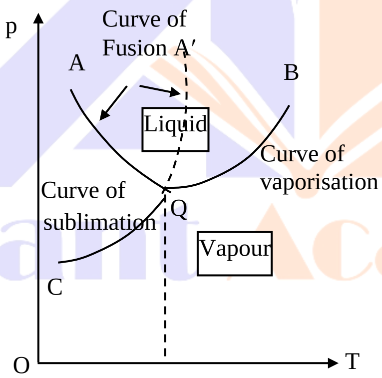
(i) It does not indicate the direction in which the exchange of heat and work can take place.

(ii) It imposes no restriction on the extent of transfer of mechanical work to heat. However, there is a limit in the reverse process although first law is not violated.

(iii) It does not indicate on whether the source is at a higher temperature or at a lower temperature.

A law that decides whether a process allowed by the first law actually takes place is called the 2nd law of thermodynamics.

Phase diagram: Any two phases of a substance coexist in thermal equilibrium for a set of values of pressure p and temperature T. If this set of values is represented on a pT diagram, a curve is obtained for each pair of phases, called phase diagram.



(i) The curve along QA or QA′ is called the fusion curve and along this curve both solid and liquid phases coexist in thermal equilibrium. QA is for ice-type substances for which the melting point decreases with pressure and QA′ is for wax-type substances for which the melting point increases with temperature.

(ii) The curve along QB is called the vaporization curve and along this curve both liquid and vapour phases coexist in thermal equilibrium.

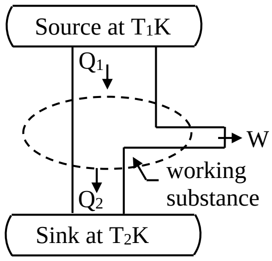
(iii) The curve along QC, called the sublimation curve and along this curve both solid and vapour phases may coexist in thermal equilibrium.

(iv) Point Q, called the triple point, is a unique point for a substance at which point all the three phases i.e., solid, liquid and vapour phases coexists in thermal equilibrium.

Reversible process

It is a process that is quasi-static and non-dissipative. Otherwise, the process is irreversible. Irreversibility is a rule of nature rather than exception.

Heat engine



It is device that transforms heat to work while operating in a cycle.

(a) Essential parts of a heat engine:

(i) **Heat source:** It is a reservoir that supplies heat at some high temperature T_1K (infinite thermal capacity).

(ii) **Heat sink:** It is reservoir that absorbs heat at some lower temperature T_2K (infinite thermal capacity) < T_1K.

(iii) **Working substance:** It is a thermodynamic system that goes through a cycle consisting of several processes.

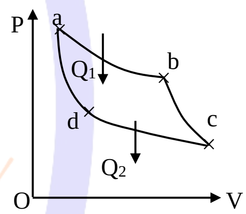
(b) Efficiency (η): It is the ratio of the work done by working substance to the heat transferred to it in every cycle.

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

$Q_1 \rightarrow$ heat transferred at T_1K, $Q_2 \rightarrow$ heat rejected to the sink at T_2K

Carnot (pronounced as carno) engine

It is an ideal reversible engine conceived by Sadi Carnot. Ideal gas is its working substance. Carnot cycle, a set of operations the working substance goes through, consists of two isothermals and two adiabatics. It has the following four steps:



(i) **Step - 1:** Isothermal expansion (curve ab) at T_1K (in contact with the heat source), absorbing heat Q_1.

(ii) **Step - 2:** Adiabatic expansion (curve bc), in contact with an insulating stand until the temperature falls to T_2K.

(iii) **Step - 3:** Isothermal compression (curve cd) at T_2K (in contact with the sink) rejecting heat Q_2.

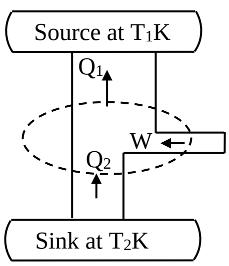
(iv) **Step - 4:** Adiabatic compression (curve da) in contact with an insulating stand, until the temperature rise to T_1K. Its efficiency is $\eta = 1 - \frac{T_2}{T_1}$

- η = 1 if either $T_2 = 0$ or $T_1 = \infty$. Either condition is unattainable. Thus, $\eta \neq 100\%$, even for a carnot engine.
- $\eta = 0$ if $T_2 = T_1$. A carnot engine cannot work without a sink.
- $Q_2 = 0$ only if $T_2 = 0$. This is the lowest attainable temperature, called the absolute zero.
- η does not depend on the nature of the working substance.
- Work done per cycle by a carnot engine is equal to the area of the loop of the carnot cycle.

Refrigerator

It is a device that transfers heat from a cold place to a warm place. It is also called heat pump. Heat transferred to the source is given by $Q_1 = (Q_2 + W)$

where W $\rightarrow$ work done on the working substance in transferring Q_2 from the sink to the source. Its performance is described by $K = \frac{Q_2}{W} = \left(\frac{Q_2}{Q_1 - Q_2}\right)$



Schematic representation of a refrigerator

- A carnot engine operated backward is a carnot refrigerator for which $K = \left(\frac{T_2}{T_1 - T_2}\right)$
- A refrigerator is perfect refrigerator if no work is done in transferring heat from the sink to the source. For a perfect refrigerator, W = 0 and K = ∞
- For household refrigerator, K = 55 (typical)
- A heat pump is used for cooling a space in summer by placing its condenser outside the space to be cooled (room) and for heating a space in winter by placing its condenser inside the room.
- Freon gas is the working substance in a refrigerator.
- Performance of refrigerator is more if (T_1 – T_2) is less. When a refrigerator is defrosted, T_2 decreases increasing K. Thus, defrosting is necessary for better performance of refrigerator.

Second law of thermodynamics

(a) **Simplest form**: Heat by itself cannot flow from a cold body to a hot body.

(b) **Kelvin-Planck statement**

(i) There exists no cycle that extracts heat from a single source at a single temperature and completely convert it to work.

(ii) Shorter version of Kelvin-Planck statement - there are no perfect engines.

(c) **Clausius statement**

(i) No process is possible whose sole net result is the transfer of heat from a lower to a higher temperature.

(ii) Shorter version of Claussius statement - There are no perfect refrigerator.

Entropy: It is defined as a state variable whose change is the ratio of heat (dQ) transferred reversibly to the temperature T at which it is transferred.

$$dS = \frac{dQ}{T}$$

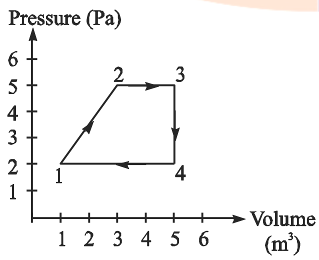
S.I. unit of entropy is J K^{-1}. Its dimensional formula is $[M^1L^2T^{-2}K^{-1}]$

Entropy and the second law of thermodynamics: In any thermodynamic process that proceeds from one equilibrium state to another, the entropy of the system + environment either remains unchanged or increases.

Illustrations

1. The graph of pressure versus volume of a monoatomic ideal gas is as shown. What is the internal energy of the system in state 1 and the heat given to the system during the process 4 to 1?

(A) 15, –5
(B) 3, –20
(C) 7, 9
(D) 7, –10



Ans (B)

$U = \frac{3}{2}pV \qquad \therefore U_1 = \frac{3}{2}(2\times1) = 3\text{ J}$

Similarly $U_2 = 22.5\text{ J},\ U_3 = 37.5\text{ J}$ and $U_4 = 15\text{ J}$

Work done during a process is given by area under *p*-*V* curve.

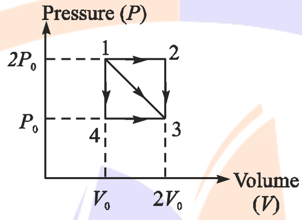
$W_{12} = \frac{1}{2}(2+5)(3-1) = 7\text{ J},\ W_{23} = 5(5-3) = 10\text{ J}, W_{34} = 0$

and $W_{41} = -2(5-1) = -8\text{ J}$

$Q_{41} = (\Delta U)_{41} + W_{41} = [3-15]+[-8] = -20\text{ J}$

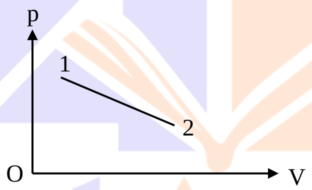
2. Figure shows the graph of pressure versus volume of an ideal gas, taken from state 1 to 3 via three different paths i.e., 123, 13 and 143. The internal energies of the gas corresponding to the states 1 and 3 are P_0V_0 and $5P_0V_0$ respectively. The works done in the processes $4 \to 3$ and $1 \to 2$ respectively are

(A) $p_0V_0, 2p_0V_0$
(B) $2p_0V_0, p_0V_0$
(C) p_0V_0, p_0V_0
(D) $2p_0V_0, 2p_0V_0$



Ans (A)
$W_{4\to3}$: Area under 43 curve $= p_0(2V_0 - V_0) = p_0V_0$
$W_{1\to2}$: Area under 12 curve = $2p_0(2V_0 - V_0) = 2p_0V_0$

3. An ideal gas goes from state 1 to state 2, as shown in the figure. The work done by the gas during the process is
(A) positive
(B) negative
(C) zero
(D) independent of the pressure



Ans (A)
Since the volume is increasing, the work done is positive

4. For nitrogen, $C_p - C_v = x$ and for argon, $C_p - C_v = y$. The relation between x and y is
(A) x = 7y (B) y = 7x (C) x = (y/2) (D) x = y
Ans (D)

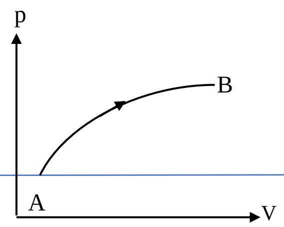
5. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is maximum when the expansion is
(A) isothermal (B) adiabatic (C) isochoric (D) same in all the cases
Ans (A)
Since in an isothermal process $\Delta U = 0$, $Q = W$ and W is maximum.

6. In an isothermal expansion of a gas
(A) pressure remains constant
(B) temperature remains constant
(C) density remains constant
(D) pV^2 = constant
Ans (B)

7. The ratio of specific heats of a gas at constant pressure to that at constant volume is γ. The change in the internal energy of one mole of a gas, when volume changes from V to 2V at constant pressure p is
(A) $\frac{R}{\gamma-1}$ (B) pV (C) $\frac{pV}{\gamma-1}$ (D) $\frac{\gamma pV}{\gamma-1}$
Ans (C)

$$\Delta U = nC_v\Delta t = \frac{nR}{\gamma-1}\Delta t = \frac{p\Delta V}{\gamma-1} = \frac{pV}{\gamma-1} \qquad (\because \Delta V = 2V - V)$$

8. In the figure given below, the work done in the process
(A) increase with time



(B) decreases with time

(C) remains constant with time

(D) is independent of volume

Ans (A)

As seen from the graph, the area under the curve increases with time. Thus the work done also increases with time.

9. The change in internal energy for any process between two given temperatures is

(A) the same
(B) different
(C) dependent on path
(D) independent of C_p of the gas

Ans (A)

ΔU is path independent and is given $\Delta U = nC_v\Delta T$

10. Find the amount of work done to increase the temperature of one mole of an ideal gas by 30 °C, if it is expanding under the condition, $V \propto T^{\frac{2}{3}}$ ($R = 1.99$ cal mol^{-1} K^{-1})

Solution

Given $VT^{-\frac{2}{3}} = \text{constant}$ … (1)

We have $pV = \mu RT \Rightarrow T = \dfrac{pV}{\mu R}$

Substituting in (1), $p^{-\frac{2}{3}} V^{\frac{1}{3}} = \text{constant (or) } pV^{-\frac{1}{2}} = \text{constant}$

Which is of the form $pV^n = \text{constant}$

Work done in a polytropic process $W = \dfrac{p_2V_2 - p_1V_1}{n-1} = \dfrac{\mu R\Delta T}{n-1} = \dfrac{1\times1.99\times30}{-\frac{1}{2}-1} = 39.8$ cal

11. Calculate the work done when 1 mole of a perfect gas is compressed adiabatically. The initial pressure and volume of the gas are 10^5 Nm^{-2} and 6 litres respectively. The final volume is 2 litres. Molar specific heat of the gas at constant volume is $\dfrac{5R}{2}$.

Solution: Using $p_1V_1^{\gamma} = p_2V_2^{\gamma}$ We get, $p_2 = 10^5\left(\dfrac{6}{2}\right)^{\frac{7}{5}} = 10^5\left(3^{7/5}\right)$

$$\therefore W = \frac{p_1V_1 - p_2V_2}{\gamma - 1} = \frac{10^5\times6\times10^{-3} - 10^5\times3^{\frac{7}{5}}\times2\times10^{-3}}{\frac{7}{5}-1} = -827\cdot7\,J$$

12. A perfect gas goes from state A to state B by absorbing 8×10^5 J of heat and doing 6.5×10^5 J of external work. In another process, when it is transferred between the same two states, it absorbs 10^5 J of heat. In the second process

(A) work done by the gas is 10^5 J
(B) work done on the gas is 10^5 J
(C) work done by the gas is 0.5×10^5 J
(D) work done on the gas is 0.5×10^5 J

Ans (D)

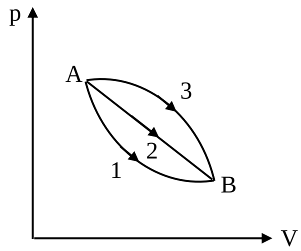
In the first process $dU = dQ - dW = 8 \times 10^5 - 6.5 \times 10^5 = 1.5 \times 10^5$ J

dU is the same for the first and the second process, since the initial and final states are the same.

Hence for the second process. $dW = dQ - dU = 1 \times 10^5 - 1.5 \times 10^5 = -0.5 \times 10^5$ J.

The negative sign indicates that work is done on the gas.

13. An ideal gas is taken from state A to state B via three different processes as shown in the figure. If Q_1, Q_2, Q_3 denote the heat absorbed in the three different processes, then



(A) $Q_1 < Q_2 < Q_3$
(B) $Q_1 > Q_2 > Q_3$
(C) $Q_1 = Q_2 = Q_3$
(D) $Q_2 = \frac{Q_1 + Q_2}{2}$

Ans (A)

From dU = (dQ – dW) ; dQ = (dU + dW) ; dU is the same for all the three processes. The area under the curves represent the work done in that process. Smaller the work done smaller is the heat absorbed.
Hence, $Q_1 < Q_2 < Q_3$.

14. 40 calories of heat is needed to raise the temperature of one mole of an ideal monoatomic gas from 20 °C to 30 °C at constant pressure. The amount of heat required to raise the temperature over the same interval of temperature at constant volume is (Given R = 2 cal mol^{-1} K^{-1})

(A) 40 cal
(B) 20 cal
(C) 30 cal
(D) 10 cal

Ans (B)

$dQ = nC_P\Delta T \Rightarrow 40 = 1 \times C_P \times 10 \Rightarrow C_P = 4$ cal mol^{-1} K^{-1}

$C_P - C_V = R \Rightarrow C_V = C_P - R = 4 - 2 = 2$ cal mol^{-1} K^{-1}

$dQ = nC_V\,\Delta T = 1 \times 2 \times 10 = 20$ cal

15. A carnot's engine works between a source at temperature T_1 and sink at temperature T_2. To increase the efficiency of the engine

(A) both T_1 and T_2 should be decreased
(B) both T_1 and T_2 should be increased
(C) T_1 should be increased but T_2 should be decreased
(D) T_1 should be decreased but T_2 should be increased

Ans (C)

The efficiency of the Carnot's engine is given by $\eta = 1 - \frac{T_2}{T_1}$

To increase η, $\frac{T_2}{T_1}$ should be decreased. This can be done by increasing T_1 and decreasing T_2.

16. A heat engine operates on Carnot cycle between 227 °C and 27 °C. If it absorbs 15×10^4 J of heat energy, then amount of heat converted into work is

(A) 5×10^4 J
(B) 6×10^4 J
(C) 7×10^4 J
(D) 8×10^4 J

Ans (B)

Efficiency of the Carnot's engine, $\eta = \left(1 - \frac{T_2}{T_1}\right) = \left[1 - \left(\frac{27 + 273}{227 + 273}\right)\right] = 1 - \frac{300}{500} = 1 - 0.6 = 0.4$

Also $\eta = \frac{\text{Work done}}{\text{heat absorbed}}$

$\therefore$ work done = $\eta \times \text{heat absorbed} = 0.4(15 \times 10^4) = 6 \times 10^4$ J

17. A refrigerator with power on and door open is kept in a closed room. The temperature of the room

(A) increases
(B) decreases
(C) remains the same
(D) may increase or decrease.

Ans (A)

The total heat delivered to the room and the work done on the system is more than the total heat withdrawn from the room. Thus the temperature in the room increases.

18. A scientist says that the efficiency of his heat engine which works at source temperature 127 °C and sink temperature 27 °C is 26 %, then

(A) it is impossible (B) it is possible but less probable

(C) it is quite probable (D) data is incomplete

Ans (A)

19. Two identical Carnot engines A and B operate between the temperatures T_1 and T_2 with $T_1 > T_2$. Suppose the source temperature of A is increased by θ, while the sink temperature of B is decreased by θ, then

(A) the efficiency of A increases (B) the efficiency of A decreases

(C) the efficiency of B increases (D) none of these

Ans (B) and (C)

$$\eta = \left(\frac{T_1 - T_2}{T_1}\right)$$

$$\eta_A = \frac{(T_1+\theta)-T_2}{T_1+\theta} \text{ and } \eta_B = \frac{T_1-(T_2-\theta)}{T_1}$$

Clearly $\eta_B > \eta$ and $\eta_A < \eta$

20. A Carnot's engine has an efficiency of $\frac{1}{3}$. The amount of work this engine can perform by heat input per kilocalorie is

(A) 1400 cal (B) 700 cal (C) 700 J (D) 1400 J

Ans (D)

$$\eta = \frac{W}{Q} \quad \therefore W = \frac{1}{3}\times 10^3 \text{cal} = \frac{1}{3}\times 4\cdot 2\times 10^3 \text{ J} = 1400 \text{ J.}$$

21. Entropy of a thermodynamic system does not change when this system is used for

(A) conduction of heat from higher to lower temperature

(B) conversion of heat in to work isobarically

(C) conversion of heat in to internal energy isochorically

(D) conversion of work in to heat ischorically.

Ans (D)

1. 1 gm of water is changed from its liquid to vapour phase. The measured latent heat of water is 2256 J/g. What is the amount of change in internal energy? [NCERT Pg. 308]
(1) 169.2 J (2) 3068.2 J (3) 2086.8 J (4) 2548.3 J

2. A monoatomic ideal gas undergoes an adiabatic process from temperature 300 K to 600 K. The gas has 2 moles, calculate work done by this ideal gas. [NCERT Pg. 312]
(1) 600 R(J) (2) -200 R(J) (3)-450R(J) (4) -900 R (J)

3. A reversible cyclic heat engine absorbs 900 joule of heat from source. If 400 J of heat is released to the sink, what is the efficiency of the engine? [NCERT Pg. 314]
(1) $\frac{2}{9}$ (2) $\frac{3}{7}$ (3) $\frac{5}{9}$ (4) $\frac{4}{9}$

4. In an isothermal process, two moles of an ideal gas expands from volume 2 m^3 to 8 m^3 at temperature of 227°C. Heat absorbed by the gas during process is nearly
[NCERT Pg. 311]
(1) 2752 cal (2) 3250 caL (3) 1945 cal (4) 1875 cal

5. In a refrigerator, the system extracts heat of 600 J from a cold reservoir and released 900 J of heat to hot reservoir. The coefficient of performance of a refrigerator is given by
[NCERT Pg, 314]
(1)2 (2)3 (3) 6 (4) 9

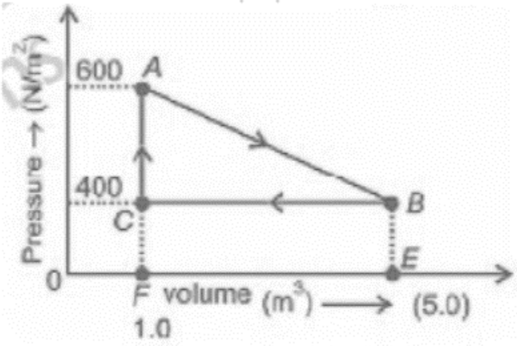
6. What amount of heat must be supplied to 210^{-2} kg of nitrogen at room temperature to raise its temperature, by 25°C at constant pressure? (Molecular wt. of $\mathbf{N_2}$ = 28)
[NCERT Pg. 321]
(1) 270.5 J (2) 519.6 J (3) 370.4 J (4) 148.3 J

7. In changing the state of a gas adiabatically from an equilibrium state *A* to another equilibrium state S, an amount of work equal to 104.6 J is done on the system. If this gas is taken from state *A* to *B* via a process in which the net heat absorbed by the system is 35 cal, how much is net work done by the system in later case? (1 cal = 4.19 J)
[NCERT Pg.321]
(1) 192.7 J (2) 89.6 J (3) 42.05 J (4) 142.5 J

8. A cylinder with movable piston contains 2 moles of hydrogen at standard temperature and pressure. The cylinder walls of the cylinder are made of heat insulator. By what factor does the pressure of a gas increase when gas is suddenly compressed to half of its Original volume? [NCERT Pg. 321]
(l) 1.5 (2) 3.82 (3) 2.64 (4) 6.23

9. Two cylinders *A* and *B* of equal capacity are connected to each other via a stopcock. *A* contains a gas at standard temperature and pressure. *B* is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. What is effect on internal energy of gas? [NCERT Pg. 321]
(1) Increases (2) Decreases
(3) No change (4) May decrease or no change

10. A thermodynamic system is taken from original state to another intermediate state by linear process shown in diagram. Its volume is then reduced to original volume from *B* to C by an isobaric process. What is total work done by gas from *A* to 6 to C?



[NCERT Pg. 322]

(1) 500 J (2) 400 J (3) 1200 J (4) 2000 J

11. A steam engine working like an ideal heat engine delivered 5.410^8 J of work per minute and takes 3.610^9 J of heat per minute from its boiler at 127°C. What is sink temperature? [NCERT Pg. 322]

(1) 37°C (2) 47°C (3) 57°C (4) 67°C

12. A diatomic gas with three moles are in a container at 400 K. Under isobaric process, its temperature is changed to 900 K. How much heat is absorbed by the gas during this process? [NCERT Pg. 312]

(1) 6.4 kcal (2) 9.4 kcal (3) 10.4 kcal (4) 12.4 kcal

13 Which of the following is incorrect statement? [NCERT Pg.315]

(1) Free expansion of a gas is irreversible process

(2) A thermodynamic process is reversible if process can be turned back **SO** that both system and surrounding return to their original states

(3) No process is possible whose sole result is transfer of heat from a colder object to hotter object

(4) The efficiency of an ideal heat engine is unity.

14. In thermodynamic processes, correct match of column-I with column-II is [NCERT Pg.306]

Column-l	Column-ll
Type of process	Feature
a. Isothermal	(i) Volume constant
b. Isobaric	(ii) Pressure constant
c. Isochoric	(iii) No heat flow between system and surroundings
d. Adiabatic	(iv) Temperature constant

(1) a(i), b(ii), c(iii). d(iv) (2) a(iv), b(l). c(iii). d(ll)

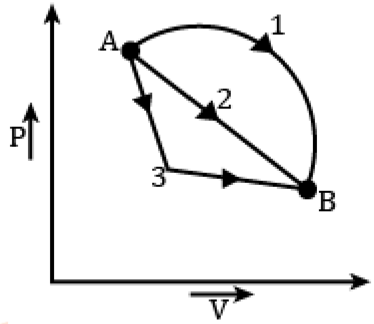
(3) a(iv), b(ii), c(iii),d(i) (4) a(iv), b(ii), c(i), d(iii)

15. Molar specific heat of an ideal gas at constant volume is 21 joule/mol K and molar specific heat at constant pressure is about 35 joule/mol K. The ideal gas is [NCERT Pg. 314]

(1) Monoatomic (2) Diatomic

(3) Triatomic (4) Polyatomic

16. An ideal gas goes from state *A* to state *B* via three different processes as indicated in *P* - *V* diagram. If Q_1, Q_2 and Q_3 indicate the heat absorbed by gas along the three processes $\Delta U_1, \Delta U_2$ and ΔU_3 and indicate the change in internal energy along three processes, then [NCERT Pg. 306]



(1) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

(2) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

(3) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

(4) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

17. If Q, E and W denote respectively the heat added, change in internal energy and work done in a closed cyclic process, then [NCERT Pg. 312]
(1) Q = 0 (2) Q= W=0 (3) W= 0 (4) E = 0

18. Thermodynamic state variables may be [NCERT Pg. 310]
(1) Extensive only (2) Intensive only
(3) Both (1)and (2) (4) Neither (1) nor (2)

19. An ideal gas is compressed to half of its initial volume by means of different thermodynamic processes. Which of the process result in the maximum work done on the gas? [NCERT Pg. 312]
(1) Isothermal (2) Adiabatic
(3) Isobaric (4) Isochoric

20. Refrigerator is to maintain eatables kept inside at 7°C. If the room temperature is 43°C, coefficient of performance of refrigerator must be [NCERT Pg. 322]
(1) 7.78 (2) 13.7 (3) 9.72 (4) 0.75

NCERT BASED PRACTICE QUESTIONS

1 The concept of temperature comes from:-
(a) zeroth law of thermodynamics (b) 1st law of thermodynamics
(c) 2nd law of thermodynamics (d) none of these

2. In thermodynamics which is a state variable
(a) work (b) heat
(c) internal energy (d) all of these

3. Which law of thermodynamics is simply the general law of energy conservation?
(a) zeroth law (b) 1st law
(c) 2nd law (d) none of these

4. If w is the work done by the gas in an isothermal expansion
(a) w > 0 (b) w < 0
(c) w = 0 (d) none of these

5. If w is the work done on the gas in an isothermal compression
(a) w > 0 (b) w < 0 (c) w = 0 (d) none of these

6. For an ideal gas, internal energy depends on
(a) temperature (b) temperature and pressure

(c) pressure and volume (d) all of these

7. If an ideal gas goes from (P_1,V_1,T_1) to (P_2,V_2, T_2) adiabatically and work done by the gas is positive (w >0) then

(a) $T_1 = T_2$ (b) $T_1>T_2$ (c) $T_1 < T_2$ (d) none of these

8. If an ideal gas goes from (P_1,V_1,T_1) to (P_2,V_2, T_2) adiabatically and work done by the gas is negative (w < 0) then

(a) $T_1 = T_2$ (b) $T_1>T_2$ (c) $T_1 < T_2$ (d) none of these

9. For a cyclic process

(a) $\Delta Q = 0$ (b) $\Delta T = 0$

(c) $\Delta U = 0$ (d) all of these

10. For a cyclic process

(a) $\Delta Q = w$ (b) $\Delta T = 0$

(c) $\Delta U = 0$ (d) all of these

11. Which law of thermodynamics restricts the efficiency of heat engine not to be1

(a) zeroth law (b) first law

(c) second law (d) none of these

12 A geyser heats water flowing at the rate of 3.0 litres per minute from 27 ^{0}C to 77 ^{0}C. If the geyser operates on a gas burner, what is the rate of consumption of the fuel is its heat of combustion is 4.0 10^4 J/g?

(a) 16 gm min^{-1} (b) 16 gm cm

(c) 16 mg (d) None

13 What amount of heat must be supplied to 2.0×10^{-2} kg of nitrogen (at room temperature) to raise its temperature by 45^{0}C at constant pressure?
(Molecular mass of N_2 = 28; R = 8.3 J $mol^{-1} K^{-1}$.)

(a) 930 J (b) 934 J

(c) 934 erg (d) None

14 In a reversible isochoric change.

(a) $\Delta w = 0$ (b) Δ r = 0

(c) $\Delta T= 0$ (d) $\Delta V=0$

15 A process in which the volume remaining constant is called

(a) Isobaric (b) Isochoric

(c) Isothermal (d) Non

16 A steam engine delivers 5.410^{8}J of work per minute and services 3.610^{9}J of heat per minute from its boiler. What is the efficiency of the engine ?

(a) 15% (b) 15.7%

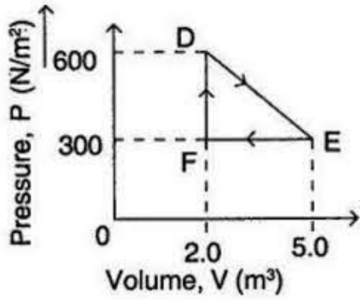
(c) 16% (d) None

17 An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 joules per second. At what rate is the internal energy increasing ?

(a) 24 J (b) 25 W

(c) 25 J (d) None

18 A thermodynamic system is taken from an original state D to an intermediate state E by the linear process shown in Fig. Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F.



(a) 450 J (b) 450 erg (c) 4.5 J (d) None

19 A refrigerator is to maintain eatables kept inside at 9^0C. If room temperature is 36^0C, calculate the co-efficient of performance

(a) 104 (b) 10.4 (c) 1.04 (d) None

20. Two vessel of the same volume contain the same gas at same temperature. If pressure in the vessel are in ratio of 1 : 2 then-

(1) Ratio of vrms is 1 : 2

(2) Ratio of average kinetic energy is 1 : 1

(3) Ratio of average velocity is 1 : 2

(4) Ratio of number of molecules is 1 : 2

21. Consider the following two statements

(A) If heat is added to a system, its temperature must increase.

(B) If positive work is done by a system in a thermodynamic process, its volume must increase.

(1) Both A & B are correct (2) A is correct but B is wrong

(3) B is correct but A is wrong (4) Both A & B are wrong

22. A gas is contained in a metallic cylinder fitted with a piston. The piston is suddenly moved in to compress the gas and is maintained at this position. As time passes the pressure of the gas in the cylinder.

(1) Increases (2) Decreases

(3) Remains constant (4) Depends on the nature of gas

23. Which of the following can be called as thermodynamic property.

(A) $\int PdV$ (B) $\int VdP$ (C) $\int PdV + \int VdP$

(1) Both A & B (2) Both B & C (3) All three (4) Only C

24. For any reversible process, the change in the entropy of the system and surroundings is

(1) 0 (2) 1 (3) infinity (4) None of these

25. Which of the following is correct according to Claussius statement of second law of thermodynamics.

(1) It is possible to transfer heat from a low temp. reservoir to a high temp. reservoir.

(2) No heat engine can have 100% efficiency.

(3) No process is possible whose sole result is the transfer of heat from a colder object to a hotter object

(4) None of these

26. In T-S diagram ratio of slope of an isobaric curve and an isochoric curve is.

(1) g (2)1/g (3) g^2 (4) Zero

27. Consider four heat reservoirs A, B, C, D. An engine working between A and C has an efficiency which is mean of efficiencies of same engine working between AB and AD. Then absolute temperture of C will be : (A is source)

(1) Geometric mean of temperature of A & D

(2) Arithmetic mean of temperature of B & D

(3) Harmonic mean of temperature of A & D

(4) Sum of temperatures of A and D.

28. Which of the following statements is correct for any thermodynamic system

(1) internal energy changes in all processes.

(2) internal energy and entropy are state functions.

(3) change in entropy can never be zero.

(4) work done in an adiabatic process is always zero.

29. Which of the following statement is incorrect.

(1) All reversible cycles have same efficiency.

(2) Reversible cycle has more efficiency than an irreversible one.

(3) Carnot cycle is a reversible one.

(4) Carnot cycle has the maximum efficiency in all cycles.

30. The coefficient of performance (b) of a heat pump is given by

(1) $\frac{Q_2}{W}$ (2) $\frac{W}{Q_2}$ (3) $\frac{Q_1}{W}$ (4) $\frac{W}{Q_1}$

31. Molar specific heat capacity of substance does not depend on-

(1) Nature of the substance

(2) Temperature of the substance

(3) Amount of the substance

(4) Condition under which heat is supplied

32. Which of the following is meaningful statement

(1) A gas in a given state has a certain amount of heat

(2) A gas in a given state has a certain amount of work

(3) A gas in a given state has a certain amount of internal energy

(4) all statements are meaningless

33. One calorie is defined to be the amount of heat required to raise the temperature of 1g of water from ..... at 1 atm.

(1) 0°C to 1°C (2) 10°C to 11°C

(3) 4°C to 5°C (4) 14.5°C to 15.5°C

34. Which of the following statement is not correct-

(1) The efficiency of the carnot heat engine depends only on the temperatures of the source and sink between which the engine works.

(2) The efficiency of a heat engine can never be unity.

(3) For a refrigerator, the co-efficient of performance can never be infinite

(4) None of these

35. The pressure P and volume V of an ideal gas both increase in a process-

(i) Such a process is not possible

(ii) The work done by the system is positive

(iii)The temperature of the system must increase.

(iv)Heat supplied to the gas is equal to the change in internal energy

(1) (i), (ii) (2) (ii), (iii) (3) (iii), (iv) (4) (i), (iv)

36. Which of the following statement is correct-

(1) Extensive variables are internal energy (U),Volume (V) and Pressure (P).

(2) Intensive variables are pressure (P),Temperature (T) and total mass (M)

(3) Extensive variables are volume (V), total mass (M) and internal energy (U)

(4) Intensive variables are temperature, density(P) and volume (V)

37. In case of water from 0°C to 4°C

(i) Volume decreases and density of water is maximum at 4°C

(ii) DW will be negative, since volume decreases

(iii)$C_p > C_v$

(iv)$C_p < C_v$

(1) (i), (ii) (2) (ii), (iii) (3) (iii), (iv) (4) (i), (ii) & (iv)

38. Which of the following statement is correct.

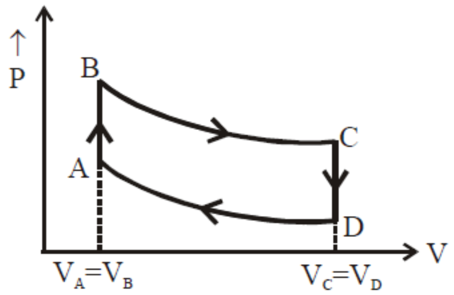
(1) If heat is added to a system, its temperature must increase.

(2) If positive work is done by a system in a thermodynamic process, its volume must increase.

(3) In free expansion, heat is necessarly absorbed by the system.

(4) In a process, the initial pressure and volume are equal to the final pressure and volume then the net work done by the system in the process must be zero.

39. A cycle followed by an engine [made of one mole of perfect gas (g=5/3) in a cylinder with a piston is shown in figure.



A to B : Volume constant

B to C : Adiabatic

C to D : Volume constant

D to A : Adiabatic and $V_C = V_D = 2V_A = 2V_B$

which of the following statement is wrong -

(1) In AB part of the cycle heat is supplied to the engine from outside

(2) In CD part of the cycle heat is being given to the surrounding by the engine

(3) In DA part of the cycle internal energy of the system increases

(4) In BC part of the cycle internal energy of the system increases

40. Heat is added to an ideal gas and the gas expands. In such a process the temperature-

(1) must increase (2) will remain same

(3) must decrease (4) can not say

41. Under isobaric condition if the temperature of a room increases then-

(1) Total KE of the molecules increases.

(2) The KE of the molecules decreases.

(3) Total KE of the molecules remain same.

(4) The density of air increases.

42. An ideal gas contained in a cylinder by a frictionless piston is allowed to expand such that temperature remains constant then work done by the gas-

(1) Zero

(2) Positive

(3) Negative

(4) May increase or decrease

43. During the melting of a slab of ice at 273K at atomospheric pressure-

(1) Work done by ice plus water system on atmosphere is positive

(2) Work done on ice plus water system by atmosphere is positive

(3) Internal energy of ice plus water system increases

(4) Both (2) and (3)

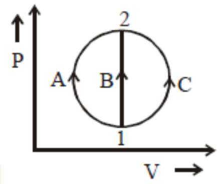
44. For a given process on an ideal gas $dW = 0$ & $dQ < 0$ then for the gas-

(1) Temp will decrease

(2) Vol. will increase

(3) pressure will remain constant
(4) Temp will increase

45. An ideal gas changes in states from 1 to 2 through three different processes A, B, C as shown



Then work done during the processes are W_A, W_B & W_C. Choose the correct option.
(1) $W_A = W_B = Wc$ (2) $W_A > W_B > Wc$
(3) $W_A = W_C > W_B$ (4) $W_C > W_A > W_B$

46. A glass of water is stirred and then allowed to stand until the water stops moving. Then internal energy of water -
(1) remains constant (2) will increase (3) will decrease (4) nothing can be said

47. If an ideal gas is compressed suddenly then-
(1) It's temperature will increase (2) It's temperature will decrease
(3) Temperature remains constant (4) None of the above

48. If a float heat engine on the ocean extract heat from water and convert into mechanical work. Is it possible?
(1) Yes, from 1st law of thermodynamic
(2) No, from 1st law of thermodynamic
(3) Yes, from 2nd law of thermodynamic
(4) Yes, from both 1st and 2nd law of thermodynamic

49. For a spontaneous process of the system, where S is entropy.
(1) DS > 0 (2) DS = 0 (3) DS < 0 (4) None of the above

50. A piston is slowly pushed into a metal cylinder isothermally containing an ideal gas then incorrect statement is-
(1) Pressure of the gas increases.
(2) Average speed of the gas molecules increases.
(3) The number of molecules per unit volume increases
(4) None of these

TOPIC WISE PRACTICE QUESTIONS

TOPIC 1: Zeroth Law and First Law of Thermodynamics

1. The first law of thermodynamics expresses
1) law of conservation of momentum 2) law of conservation of energy
3) law of conservation of mass 4) All of the above

2. Which of the following parameters does not characterize the thermodynamic state of matter?
1) Temperature 2) Pressure 3) Work 4) Volume

3. The internal energy of an ideal gas does not depend upon
1) temperature of the gas 2) pressure of the gas
3) atomicity of the gas 4) number of moles of the gas.

4. The internal energy change in a system that has absorbed 2 Kcal of heat and done 500 J of work is
1) 8900 J 2) 6400 J 3) 5400 J 4) 7900 J

5. 110 joules of heat is added to a gaseous system, whose internal energy is 40J; then the amount of external work done is
1) 150 J 2) 70 J 3) 110 J 4) 40 J

6. In a given process on an ideal gas, $dW = 0$ and $dQ < 0$. Then for the gas
1) the temperature will decrease 2) the volume will increase
3) the pressure will remain constant 4) the temperature will increase

7. At a given temperature the internal energy of a substance
1) in liquid state is equal to that in gaseous state 2) in liquid state is less than that in gaseous state
3) in liquid state is more than that in gaseous state 4) is equal for the three states of matter

8. If the amount of heat given to a system is 35 J and the amount of work done on the system is 15 J, then the change in internal energy of the system is
1) –50 J 2) 20 J 3) 30 J 4) 50 J

9. Which of the following is incorrect regarding first law of thermodynamics?
1) It is a restatement of principle of conservation of energy.
2) It is applicable to cyclic processes
3) It introduces the concept of entropy
4) It introduces the concept of internal energy

10. If a system undergoes contraction of volume then the work done by the system will be
1) zero 2) negative 3) positive 4) negligible

11. A system X is neither in thermal equilibrium with Y nor with Z. The systems Y and Z
1) must be in thermal equilibrium 2) cannot be in thermal equilibrium
3) may be in thermal equilibrium 4) None of these

TOPIC 2: Specific Heat Capacity, Thermodynamic Processes

12. In the equation PV^{γ} = constant, the value of γ is unity. Then the process is
1) isothermal 2) adiabatic 3) isobaric 4) irreversible

13. The slopes of isothermal and adiabatic curves are related as
1) isothermal curve slope = adiabatic curve slope
2) isothermal curve slope = $\gamma \times$ adiabatic curve slope
3) adiabatic curve slope = γ $\times$ isothermal curve slope
4) adiabatic curve slope= $\frac{1}{2} \times$ isothermal curve slope

14. A monoatomic gas at a pressure P, having a volume V expands isothermally to a volume 2V and then adiabatically to a volume 16V. The final pressure of the gas is :
(take $\gamma = \frac{5}{3}$)
1) 64P 2) 32P 3) $\frac{P}{64}$ 4) 16P

15. A diatomic ideal gas is compressed adiabatically to of its initial volume. If the initial temperature of the gas is Ti (in Kelvin) and the final temperature is $a\ Ti$, the value of a is
1) 8 2) 4 3) 3 4) 5

16. The relation between U, P and V for an ideal gas in an adiabatic process is given by relation $U = a + bPV$. Find the value of adiabatic exponent (γ) of this gas.

1) $\frac{b+1}{b}$ 2) $\frac{b+1}{a}$ 3) $\frac{a+1}{b}$ 4) $\frac{a}{a+b}$

17. Which of the following processes is adiabatic ?

1) melting of ice
2) bursting of tyre
3) motion of piston of an engine with constant speed
4) None of these

18. A point on P – V diagram represents

1) the condition of a system 2) work done on or by the system
3) work done in a cyclic process 4) a thermodynamic process

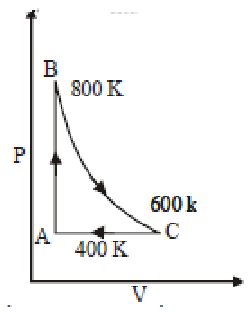
19. Choose the incorrect statement related to an isobaric process.

1) $\frac{V}{T} = \text{constant}$ 2) $W = P\Delta V$
3) Heat given to a system is used up in raising the temperature only.
4) $\Delta Q > W$

20. When heat is given to a gas in an isothermal change, the result will be

1) external work done 2) rise in temperature
3) increase in internal energy 4) external work done and also rise in temperature

21. One mole of a diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K, 800 K and 600 K respectively. Choose the correct statement:

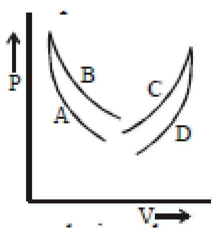


1) The change in internal energy in whole cyclic process is 250 R.
2) The change in internal energy in the process CA is 700 R.
3) The change in internal energy in the process AB is -350 R.
4) The change in internal energy in the process BC is – 500 R.

22. An ideal gas is initially at P_1, V_1 is expanded to P_2, V_2 and then compressed adiabatically to the same volume V_1 and pressure P_3. If W is the net work done by the gas in complete process which of the following is true ?

1) $W > 0$; $P_3 > P_1$ 2) $W < 0$; $P_3 > P_1$ 3) $W > 0$; $P_3 < P_1$ 4) $W < 0$; $P_3 < P_1$

23. Four curves A, B, C and D are drawn in the figure for a given amount of a gas. The curves which represent adiabatic and isothermal changes are



1) C and D respectively 2) D and C respectively 3) A and B respectively 4) B and A respectively

24. An ideal gas *A* and a real gas *B* have their volumes increased from *V* to 2*V* under isothermal conditions. The increase in internal energy

1) will be same in both *A* and *B* 2) will be zero in both the gases
3) of *B* will be more than that of *A* 4) of *A* will be more than that of *B*

25. A cube of side 5 cm made of iron and having a mass of 1500g is heated from 25° C to 400°C. The specific heat for iron is 0.12 cal/g°C and the coefficient of volume expansion is3.5×10^{-5}/°C, the change in the internal energy of the cube is (atm pressure = 1×10^5 N/m^2)

1) 320 kJ 2) 282 kJ 3) 141 kJ 4) 423 kJ

26. At 27ºC a gas is compressed suddenly such that its pressure becomes (1/8) of original pressure. Final temperature will be(γ = 5/3)

1) 450 K 2) 300 K 3) –142ºC 4) 327ºC

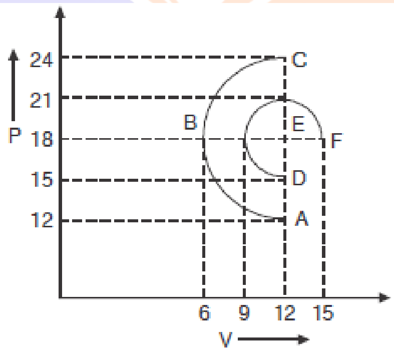
27. A sample of gas expands from volume V1 to V2. The amount of work done by the gas is greatest when the expansion is

1) isothermal 2) isobaric 3) adiabatic 4) equal in all cases

28. When an ideal gas (γ = 5/ 3) is heated under constant pressure, then what percentage of given heat energy will be utilised in doing external work?

1) 40% 2) 30% 3) 60% 4) 20%

29. There are two processes ABC and DEF. In which of the process is the amount of work done by the gas greater?



1) ABC 2) DEF 3) Equal in both processes 4) It cannot be predicted

30. Unit mass of a liquid with volume *V*1 is completely changed into a gas of volume *V*2 at a constant external pressure *P* and temperature *T*. If the latent heat of evaporation for the given mass is *L*, then the increase in the internal energy of the system is

1) Zero 2) *P*(*V*2 – *V*1) 3) *L* – *P*(*V*2 – *V*1) 4) *L*

31. The temperature of 5 moles of a gas which was held at constant volume was changed from 100º to 120ºC. The change in the internal energy of the gas was found to be 80 joule, the total heat capacity of the gas at constant volume will be equal to

1) 8 joule per K 2) 0.8 joule per K 3) 4.0 joule per K 4) 0.4 joule per K

32. Specific heat of gas in adiabatic process is

1) zero 2) infinite 3) 1 4) 150

33. During an adiabatic process an object does 100J of work and its temperature decreases by 5K. During another process it does 25J of work and its temperature decreases by 5K. Its heat capacity for 2nd process is

1) 20 J/K 2) 24 J/K 3) 15 J/K 4) 100 J/K

34. A mass of ideal gas at pressure P is expanded isothermally to four times the original volume and then slowly compressed adiabatically to its original volume. Assuming γ to be 1.5, the new pressure of the gas is

1) 2 P 2) P 3) 4 P 4) P/2

35. On *P-V* coordinates, the slope of an isothermal curve of a gas at a pressure P = 1M Pa and volume V = 0.0025 m^3 is equal to –400 MPa/m^3. If $C_p / C_v = 1.4$, the slope of the adiabatic curve passing through this point is :

1) –56 MPa/m^3 2) –400 MPa/m^3 3) –560 MPa/m^3 4) None of these

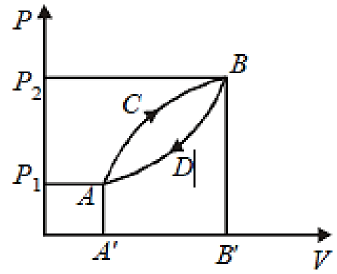
36. An ideal gas at atmospheric pressure is adiabatically compressed so that its density becomes 32 times of its initial value. If the final pressure of gas is 128 atmospheres, the value of γ of the gas is :

1) 1.5 2) 1.4 3) 1.3 4) 1.6

37. An ideal monatomic gas with pressure P, volume V and temperature T is expanded isothermally to a volume $2V$ and a final pressure Pi. If the same gas is expanded adiabatically to a volume $2V$, the final pressure is Pa. The ratio $\frac{P_a}{P_i}$ is

1) $2^{-1/3}$ 2) $2^{1/3}$ 3) $2^{2/3}$ 4) $2^{-2/3}$

38. A thermodynamic system is taken from state A to B along *ACB* and is brought back to A along *BDA* as shown in the *PV* diagram. The net work done during the complete cycle is given by the area



1) $P_1ACBP_2P_1$ 2) $ACBB'A'A$ 3) ACBDA 4) $ADBB'A'A$

39. One mole of an ideal gas at an initial temperature of *TK* does 6R joules of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be

1) $(T-4)\,K$ 2) $(T+2.4)\,K$ 3) $(T-2.4)\,K$ 4) $(T+4)\,K$

40. An ideal gas at 27ºC is compressed adiabatically to 8/27 of its original volume. The rise in temperature is $\left(\gamma = \frac{5}{3}\right)$

1) 475ºC 2) 375ºC 3) 275ºC 4) 175ºC

41. If the ratio of specific heat of a gas at constant pressure to that at constant volume is g, the change in internal energy of a mass of gas, when the volume changes from V to $2V$ at constant pressure P, is

1) $\frac{R}{(\gamma-1)}$ 2) PV 3) $\frac{PV}{(\gamma-1)}$ 4) $\frac{\gamma PV}{(\gamma-1)}$

42. An ideal gas undergoing adiabatic change has the following pressure-temperature relationship

1) $P^{\gamma-1}T^{\gamma}$ = constant 2) $P^{\gamma}T^{\gamma-1}$ = constant 3) $P^{\gamma}T^{1-\gamma}$ = constant 4) $P^{1-\gamma}T^{\gamma}$ = constant

43. The pressure inside a tyre is 4 times that of atmosphere. If the tyre bursts suddenly at temperature 300 K, what will be the new temperature?

1) $300(4)^{7/2}$ 2) $300(4)^{2/7}$ 3) $300(2)^{7/2}$ 4) $300(4)^{-2/7}$

44. A diatomic gas initally at 18ºC is compressed adiabatically to one eighth of its original volume. The temperature after compression will be
1) 18ºC 2) 887ºC 3) 327ºC 4) 395.5ºC

45. In isothermal process
1) internal energy remains constant 2) specific heat of gas is zero
3) exchange of heat does not occur 4) internal energy decreases

TOPIC 3: Carnot Engine, Refrigerator and Second Law of Thermodynamics

46. Even Carnot engine cannot give 100% efficiency because we cannot
1) prevent radiation 2) find ideal sources 3) reach absolute zero temperature 4) eliminate friction

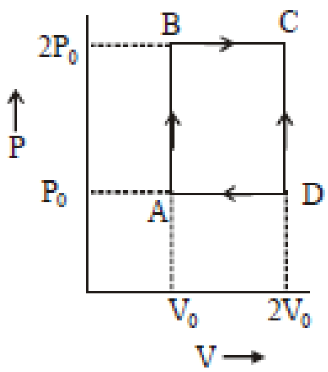
47. A refrigerator is a
1) heat engine 2) an electric motor 3) heat engine working in backward direction 4) air cooler

48. A carnot engine takes in 3000 kcal of heat from a reservoir at 627°C and gives it to a sink at 27°C. The work done by the engine is
1) 4.2×10^6 J 2) 8.4×10^6 J 3) 16.8×10^6 J 4)zero

49. In Carnot engine efficiency is 40% at hot reservoir temperature T. For efficiency 50% what will be temperature
of hot reservoir?
1) $\frac{T}{5}$ 2) $\frac{2T}{5}$ 3) 6T 4) $\frac{6T}{5}$

50. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or
consequence of
1) second law of thermodynamics 2) conservation of momentum
3) conservation of mass 4) first law of thermodynamics

51. An engine operates by taking n moles of an ideal gas through the cycle ABCDA shown in figure. The thermal efficiency of the engine is : (Take C_v =1.5 R, where R is gas constant)



1) 0.24 2)0.15 3)0.32 4)0.08

52. A Carnot engine whose efficiency is 40%, receives heat at 500K. If the efficiency is to be 50%, the source temperature for the same exhaust temperature is
1) 900 K 2) 600 K 3) 700 K 4) 800 K

53. If the temperatures of source and sink of a Carnot engine having efficiency h are each decreased by 100 K, then the efficiency
1) remains constant 2) becomes 1 3) decreases 4) increases

54. The coefficient of performance of a refrigerator is 5. If the inside temperature of freezer is -20°C, then the temperature of the surroundings to which it rejects heat is

1) 41°C 2) 11°C 3) 21°C 4) 31°C

55. If the energy input to a Carnot engine is thrice the work it performs then, the fraction of energy rejected to the sink is

1) 1/3 2) 1/4 3) 2/5 4) 2/3

56. A Carnot engine absorbs 1000 J of heat energy from a reservoir at 127°C and rejects 600 J of heat energy during each cycle. The efficiency of engine and temperature of sink will be:

1) 20% and – 43°C 2) 40% and – 33°C 3) 50% and – 20°C 4) 70% and – 10°C

57. An ideal gas heat engine operates in Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cals of heat at higher temperature. Amount of heat converted to work is

1) 4.8×10^4 cals 2) 6×10^4 cals 3) 2.4×10^4 cals 4) 1.2×10^4 cals

58. A carnot's engine takes 300 calories of heat at 500 K and rejects 150 calories of heat to the sink. The temperature of the sink is

1) 1000 K 2) 750 K 3) 250 K 4) 125 K

59. The first operation involved in a carnot cycle is

1) isothermal expansion 2) adiabatic expansion
3) isothermal compression 4) adiabatic compression

60. Which of the following processes is reversible?

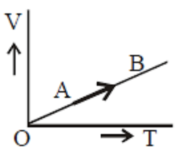
1) Transfer of heat by conduction 2) Transfer of heat by radiation
3) Isothermal compression 4) Electrical heating of a nichrome wire

NEET PREVIOUS YEARS QUESTIONS

1. The efficiency of an ideal heat engine working between the freezing point and boiling point of water, is **[2018]**

1) 26.8% 2) 20% 3) 12.5% 4) 6.25%

2. The volume (V) of a monatomic gas varies with its temperature (T), as shown in the graph. The ratio of work done by the gas, to the heat absorbed by it, when it undergoes a change from state A to state B, is **(2018)**



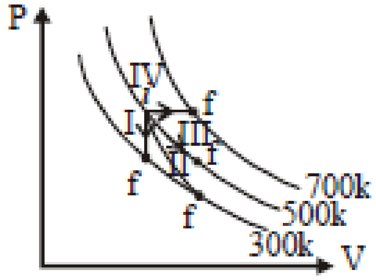
1) 2/5 2)2/3 3)2/7 4) 1/3

3. A sample of 0.1 g of water at 100°C and normal pressure (1.013 × 105 Nm–2) requires 54 cal of heat energy to convert to steam at 100°C. If the volume of the steam produced is 167.1 cc, the change in internal energy of the sample, is **[2018]**

1) 104.3 J 2) 208.7 J 3) 84.5 J 4) 42.2 J

4. Thermodynamic processes are indicated in the following diagram: **[2017]**

Match the following



Column-1	**Column-2**
P. Process I	A. Adiabatic
Q. Process II	B. Isobaric
R. Process III	C. Isochoric
S. Process IV	D. Isothermal

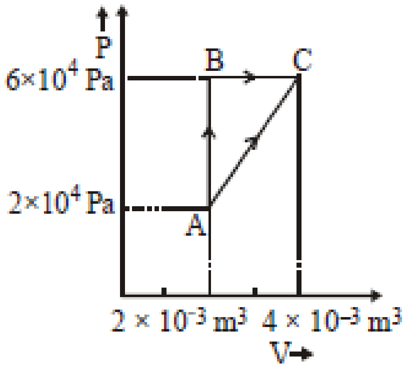
1) P $\rightarrow$ C, Q $\rightarrow$ A, R $\rightarrow$ D, S $\rightarrow$ B
2) P $\rightarrow$ C, Q $\rightarrow$ D, R $\rightarrow$ B, S $\rightarrow$ A
3) P $\rightarrow$ D, Q $\rightarrow$ B, R $\rightarrow$ A, S $\rightarrow$ C
4) P $\rightarrow$ A, Q $\rightarrow$ C, R $\rightarrow$ D, S $\rightarrow$ B

5. A carnot engine having an efficiency of 110 as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is :- **[2017]**
1) 90 J 2) 99 J 3) 100 J 4) 1 J

6. A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the temperature of the refrigerated space constant. The power required is: (Take 1 cal = 4.2 joules) **[2016]**
1) 2.365 W 2) 23.65 W 3) 236.5 W 4) 2365 W

7. A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then **[2016]**
1) Compressing the gas isothermally will require more work to be done.
2) Compressing the gas through adiabatic process will require more work to be done.
3) Compressing the gas isothermally or adiabatically will require the same amount of work.
4) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.

8. Figure below shows two paths that may be taken by a gas to go from a state A to a state C. **[2015]**
In process AB, 400 J of heat is added to the system and in process BC, 100 J of heat is added to the system. The heat absorbed by the system in the process AC will be



1) 500 J 2) 460 J 3) 300 J 4) 380 J

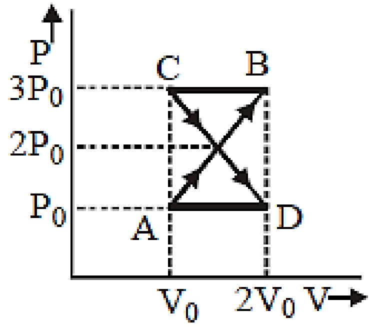
9. An ideal gas is compressed to half its initial volume by means of several processes. Which of the process results in the maximum work done on the gas? **[2015]**
1) Isobaric 2) Isochoric 3) Isothermal 4) Adiabatic

10. The coefficient of performance of a refrigerator is 5. If the inside temperature of freezer is –20°C, then the temperature of the surroundings to which it rejects heat is **[2015]**
1) 41°C 2) 11°C 3) 21°C 4) 31°C

11. A monoatomic gas at a pressure P, having a volume V expands isothermally to a volume 2V and then adiabatically to a volume 16V. The final pressure of the gas is : (take γ =5/3) **[2014]**

1) 64P 2) 32P 3)P/64 4) 16P

12. A thermodynamic system undergoes cyclic process ABCDA as shown in fig. The work done by the system in the cycle is: **[2014]**



1) P_0V_0 2) $2P_0V_0$ 3) $\frac{P_0V_0}{2}$ 4) Zero

13. In which of the following processes, heat is neither absorbed nor released by a system? **[NEET–2019]**

(1) isothermal (2) adiabatic (3) isobaric (4) isochoric

14. 1g of water, of volume 1 cm^3 at 100°C, is converted into steam at same temperature under normal atmospheric pressure $\left(\approx 1\times10^5 Pa\right)$. The volume of steam formed equals 1671 cm^3. If the specific latent heat of vaporisation of water is 2256 J/g, then the change in internal energy is **[NEET–2019 ODISSA]**

(1) 2423 J (2) 2089 J (3) 167 J (4) 2256 J

15. The efficiency of a Carnot engine depends upon **[NEET – 2020 COVID-19]**

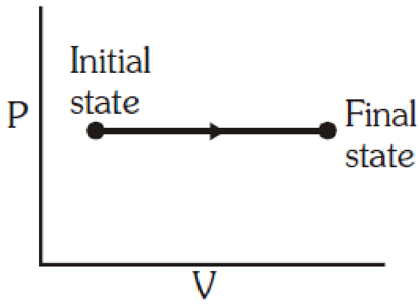
(1) the temperature of the sink only

(2) the temperatures of the source and sink

(3) the volume of the cylinder of the engine

(4) the temperature of the source only

16. The P-V diagram for an ideal gas in a piston cylinder assembly undergoing a thermodynamic process is shown in the figure. The process is **[NEET – 2020 COVID-19]**



(1) adiabatic (2) isochoric (3) isobaric (4) isothermal

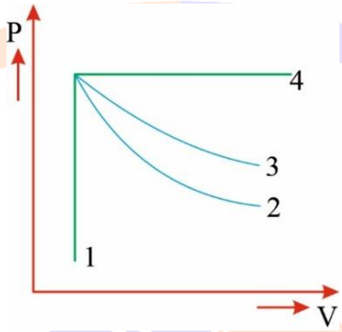
17. The quantities of heat required to raise the temperature of two solid copper spheres of radii r_1 and r_2 $\left(r_1 = 1.5\, r_2\right)$ through 1K are in the ratio **[NEET–2020]**

1) $\frac{5}{3}$ 2) $\frac{27}{8}$ 3) $\frac{9}{4}$ 4) $\frac{3}{2}$

18. Two cylinders A and B of equal capacity are connected to each other via a stop cock. A contains an ideal gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stop cock is suddenly opened. The process is **[NEET – 2020]**

1) isobaric 2) isothermal 3) adiabatic 4) isochoric

19. An ideal gas undergoes four different processes from the same initial state as shown in the figure below. Those processes are adiabatic, isothermal, isobaric and isochoric. The curve which represents the adiabatic process among 1, 2, 3 and 4 is **[NEET – 2022]**



1) 1 2) 2 3) 3 4) 4

NCERT LINE BY LINE QUESTIONS – ANSWERS

1.	(c)	2.	(d)	3.	(c)	4.	(a)	5.	(a)
6.	(b)	7.	(c)	8.	(c)	9.	(c)	10.	(b)
11.	(d)	12.	(c)	13.	(d)	14.	(d)	15.	(a)
16.	(a)	17.	(d)	18.	(c)	19.	(b)	20.	(a)

NCERT BASED QUESTONS-ANSWERS

1	a	2	c	3	b	4	a	5	b
6	a	7	b	8	c	9	c	10	c
11	c	12	d	13	d	14	a	15	b
16	a	17	b	18	a	19	b	20	4
21	3	22	2	23	4	24	1	25	3
26	2	27	2	28	2	29	1	30	1
31	3	32	3	33	4	34	4	35	2
36	3	37	4	38	2	39	4	40	4
41	3	42	2	43	4	44	1	45	2
46	2	47	1	48	1	49	1	50	2

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1) 2	2) 3	3) 2	4) 4	5) 2	6) 1	7) 2	8) 4	9) 4	10) 3
11) 3	12) 1	13) 3	14) 3	15) 2	16) 1	17) 2	18) 1	19) 3	20) 1
21) 4	22) 2	23) 3	24) 2	25) 2	26) 3	27) 1	28) 1	29) 2	30) 3
31) 3	32) 1	33) 3	34) 1	35) 3	36) 2	37) 4	38) 3	39) 1	40) 2
41) 3	42) 4	43) 4	44) 4	45) 1	46) 3	47) 3	48) 2	49) 4	50) 1
51) 2	52) 2	53) 4	54) 4	55) 4	56) 2	57) 4	58) 3	59) 1	60) 3

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1) 1	2) 1	3) 2	4) 1	5) 1	6) 3	7) 2	8) 2	9) 4	10) 4
11) 3	12) 4	13) 2	14) 2	15) 2	16) 3	17) 2	18) 3	19) 2	

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(b)** First law of thermodynamics is based on conservation of energy principle.

2. **(c)** Work is a path function. The remaining three parameters are state function.

3. **(b)** pressure of the gas

4. **(d)** $\Delta Q = \Delta U + \Delta W \Rightarrow 2 \times 10^3 \times 4.2 = \Delta U + 500$

$\Rightarrow \Delta U = 7900 J$

5. **(b)** $\Delta Q = \Delta U + \Delta W$

$\Rightarrow \Delta W = Q - \Delta U = 110 - 40 = 70$ J

6. **(a)** From the first law of thermodynamics

$dQ = dU + dW$

Here $dW = 0$ (given)

$\therefore dQ = dU$

Now since $dQ < 0$ (given)

$\therefore dQ$ is negative

$\Rightarrow dU = -$ve $\Rightarrow dU$ decreases. $\Rightarrow$ Temperature decreases.

7. **(b)** in liquid state is less than that in gaseous state

8. **(d)** According to first law of thermodynamics

$\Delta Q = \Delta U + \Delta W$

$\Delta U = \Delta Q - \Delta W$

$\Delta Q = 35J, \ \Delta W = -15J$

$\therefore \Delta U = 35J - (-15J) = 50J$

[**Note :** ΔW is negative because work is done on the system.]

9. (d) The first law of thermodynamics states the principle of conservation of energy. It introduces the concept of the internal energy. And it is applicable for any cycle. Hence, 1 and 4 are the incorrect statements regarding the first law of thermodynamics.

10. (c) Work done = Pressure × Change in volume

We are given that the system undergoes contraction. This means that V_2 will be less than V_1

11. (c) By zeroth law of thermodynamics, there are three parts to the system. Let's say x, y, z

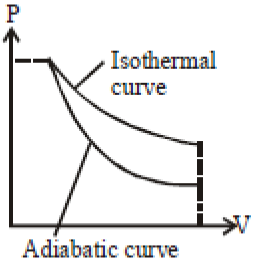
It is given that in the question is, A system Y is neither in thermal equilibrium with Y nor with Z.

But, their is possibility by Zeroth law of thermodynamics that Y and Z may be in thermal equilibrium.

12. **(a)** PV = constant represents isothermal process.

13. **(c)** $\dfrac{\text{Slope of adiabatic curve}}{\text{Slope of isothermal curve}} = \dfrac{(dP/dV)_{adi}}{(dP/dV)_{iso}} = +\gamma$

So slope to adiabatic curve is $\gamma = \left(\dfrac{C_P}{C_V}\right)$ times of isothermal curve, as clear also from figure.



14. **(c)** For isothermal process $P_1V_1 = P_2V_2$

$\Rightarrow PV = P_2(2V) \Rightarrow P_2 = \frac{P}{2}$

For adiabatic process

$$P_2V_2^{\gamma} = P_3V_3^{\gamma} \Rightarrow \left(\frac{P}{2}\right)(2v)^{\gamma} = P_3(16v)^{\gamma} \Rightarrow P_3 = \frac{3}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{64}$$

15. (b) For adiabatic process, we can write $TV^{\gamma-1}$ = constant

$\gamma = \frac{7}{5}$ for diatomic gases

$T_iV^{\frac{7}{5}-1}$ = k(constant) -------initial condition

$aT_iV^{\frac{7}{5}-1}$ = k(constant) ------final condition

$TV^{\frac{7}{5}-1} = aT\left(\frac{V}{32}\right)^{\frac{7}{5}-1}$; $\therefore a = 4$

16. (a) U = a + bPV ......(1)

In adiabatic change

$$dU = -dW = \frac{nR}{\gamma-1}(T_2 - T_1) = \frac{nR}{\gamma-1}(dT)$$

$$\Rightarrow U = \int dU = \frac{nR}{\gamma-1}\int dT$$

or $U = \left(\frac{nR}{\gamma-1}\right)T + a = \frac{PV}{\gamma-1} + a$ ......(2)

where a is the constant of integration.

Comparing (1) and (2), we get

$$b = \frac{1}{\gamma-1} \Rightarrow \gamma = \frac{b+1}{b}$$

17. **(b) Adiabatic process** is a type of thermodynamic process that occurs without any transfer of heat or mass between the thermodynamic system and environment.

Exploding of tyre is an adiabatic process because when a tyre suddenly, the expansion happens, it decreases the temperature inside the tyre. Heat transfer takes place when it explode, due to which it can be considered that there is almost no energy exchange during the actual process. Hence, it became adiabatic process.

18. (a) Every point on this isothermal curve represents the condition of a system.

19. (c) From ideal gas law, PV=nRT

In isobaric process, P is constant.

$$\text{So, } V = \frac{nR}{P}T$$

$$\Rightarrow V = kT$$

$$\therefore \frac{V}{T} = \text{constant} \quad \rightarrow (1)$$

$$W = \int P\,dV$$

$$\Rightarrow W = \int P \frac{nr\Delta T}{P}$$

$$\Rightarrow W = p\int dT$$

$$\Rightarrow W = p\Delta T \quad \rightarrow (2)$$

Heat given to the system can also decrease the temperature.

20. (a) When heat is given to a gas in an isothermal change, the result will be External work done and also rise in temp.

21. **(d)** In cyclic process, change in total internal energy is zero.

$$\Delta U_{cyclic} = 0$$

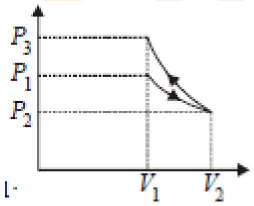
$$\Delta U_{BC} = nC_v\Delta T = 1 \times \frac{5R}{2}\Delta T$$

Where, C_V = molar specific heat at constant volume.

For BC, $\Delta T = -200$ K $\qquad \therefore \Delta U_{BC} = -500R$

22. **(b)** In the first process W is + ve as ΔV is positive, in the second process W is – ve as ΔV is – ve and area under the curve of second process is more

$\therefore$ Net Work < 0 and also $P_3 > P_1$



23. **(c)** Curve A, B shows expansion. For expansion of a gas,

$W_{isothermal} > W_{adiabatic}$

$P_{isothermal} > P_{adiabatic}$

$T_{isothermal} > T_{adiabatic}$

$\Rightarrow$ Slope of curve for isothermal change < slope of curve for adiabatic change.

So, curve B shows isothermal change and curve A shows adiabatic change.

24. **(b)** Under isothermal conditions, there is no change in internal energy.

25. **(b)** $Q = mC\Delta T = 1.5 \times 0.12 \times 4200 \times (400 - 25) = 2.83 \times 10^5$ J

$W = P(\Delta V) = P(V\gamma\Delta T)$

$= 10^5 \times (5 \times 10^{-2})^3 \times 3.5 \times 10^{-5} \times 375 = 0.164$ J

Thus $Q = \Delta U + W$

or $2.83 \times 10^5 = \Delta U + 0.164$; $\Delta U = 282$ kJ

26. (c) $T_1^{\gamma}P_1^{1-\gamma} = T_2^{\gamma}P_2^{1-\gamma}$

27. (a) At constant pressure, the PV curve enclose maximum area. Hence work will be maximum in that case compared to other processes

28. (a) $\Delta Q = \Delta U + \Delta W$

$$\Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{\Delta U}{\Delta Q} = 1 - \frac{nC_V dT}{nC_p dT} \Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{C_V}{C_p} = 1 - \frac{3}{5} = \frac{2}{5} = 0.4$$

29. **(b)** $W_{ABC}=\frac{\pi r^2}{2}=\frac{\pi(6)^2}{2}=18\pi$

$$W_{DEF}=\frac{\pi\times3^2}{2}+\frac{\pi\times3^2}{4}+(15-12)\times18=6.75\pi+54$$

$W_{DEF}>W_{ABC}$

30. **(c)** $Q = mL = 1 \times L = L$; $W = P(V_2 - V_1)$
Now $Q = \Delta U + W$ or $L = \Delta U + P(V_2 - V_1)$
$\therefore \Delta U = L - P(V_2 - V_1)$

31. **(c)** $dU = nC_V\, dT$ or $80 = 5\times C_V (120 - 100)$
$C_V = 4.0$ joule/K

32. **(a)** Zero

33. **(c)** For adiabatic process, dU = – 100 J
which remains same for other processes also.
Let C be the heat capacity of 2nd process then
$-(C)\,5 = dU + dW = -100 + 25 = -75$ $\therefore C = 15$ J/K

34. **(a)** Let P and V be the initial pressure and volume of ideal gas. After isothermal expansion, pressure is P/4. So volume is 4V.
Let P_1 be the pressure after adiabatic compression. Then
$P_1V^\gamma=(P/4)(4V)^\gamma$ $P_1=(P/4)(4)^{3/2}=2P$

35. **(c)** Slope of adiabatic curve= γ × slope of isothermal curve= 1.4 × (–400) = – 560 MP a/m^3

36. **(b)** Volume of the gas $\Rightarrow v=\frac{m}{d}$ and using PV^γ = constant

$$\frac{P^|}{P}=\frac{V}{V^|}=\left(\frac{d^|}{d}\right)^\gamma \text{ or } 128=(32)^\gamma\ ;\ \therefore \gamma=\frac{7}{5}=1.4$$

37. **(d)** For isothermal process :
$PV = P_i .2V$
$P = 2P_i$ ....(i)
For adiabatic process

$PV^\gamma=P_a(2V)^\gamma$ ($\because$ for monatomic gas γ=5/3) or $2P_iV^{\frac{5}{3}}=P_a(2V)^{\frac{5}{3}}$ [From (i)]

$$\Rightarrow\frac{P_a}{P_i}=\frac{2}{2^{\frac{5}{3}}}\Rightarrow\frac{P_a}{P_i}=2^{\frac{-2}{3}}$$

38. **(c)** Work done = Area under curve *ACBDA*

39. **(a)** $T_1 = T$, $W = 6R$ joules, $\gamma=\frac{5}{3}$

$$W=\frac{P_1V_1-P_2V_2}{\gamma-1}=\frac{nRT_1-nRT_2}{\gamma-1}=\frac{nR(T_1-T_2)}{\gamma-1}\ ;\ n=1, T_1=T\Rightarrow\frac{R(T-T_2)}{5/3-1}=6R\Rightarrow T_2=(T-4)K$$

40. **(b)** For an adiabatic process $TV^{\gamma-1}$= constant. Therefore

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

$$\Rightarrow T_2=T_1\left[\frac{V_1}{V_2}\right]^{\gamma-1}$$

$$=300\left[\frac{27}{8}\right]^{5/3-1}=300\left[\frac{27}{8}\right]^{2/3}=675K$$

$$\Rightarrow \Delta T=675-300=375K$$

41. **(c)** Change in internal energy is equal to work done in adiabatic system
$\Delta W = -\Delta U$ (Expansion in the system)

$$= -\frac{1}{\gamma-1}(P_1V_1 - P_2V_2)$$

$$\Delta U = \frac{1}{1-\gamma}(P_2V_2 - P_1V_1)$$

Here, $V_1 = V, V_2 = 2V$

$$\therefore \quad \Delta U = \frac{1}{1-\gamma}[P \times 2V - PV] = \frac{PV}{1-\gamma} \Rightarrow \Delta U = -\frac{PV}{\gamma-1}$$

42. **(d)** We know that in adiabatic process,

PV^{γ} = constant ....(1)

From ideal gas equation, we know that

$PV = nRT \Rightarrow V = \frac{nRT}{P}$ ....(2)

Putting the value from equation (2) in equation (1),

$$P\left(\frac{nRT}{P}\right)^{\gamma} = \text{constant} \Rightarrow P^{(1-\gamma)}T^{\gamma} = \text{constant}$$

43. **(d)** Under adiabatic change

$$\frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}} \text{ or } T_2 = T_1(P_1/P_2)^{\frac{1-\gamma}{\gamma}}$$

$$\therefore \quad T_2 = 300(4/1)^{\frac{1-(7/5)}{(7/5)}}; \quad \gamma = 1.4 = 7/5 \text{ for air}$$

$$\text{or} \quad T_2 = 300(4)^{-2/7}$$

44. **(d)** $T_1 = 18^0C = (273+18) = 291K$ and $V_2 = V_1/8$

We know that $TV^{\gamma-1}$ = constant or $T_2V_2^{\gamma-1} = T_1V_1^{\gamma-1}$

$$\therefore T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 291 \times (8)^{1.4-1} = 668.5K = 395.5^0C$$

45. **(a)** internal energy remains constant.

46. **(c)** In Carnot's cycle we assume frictionless piston, absolute insulation and ideal source and sink (reservoirs). The efficiency of Carnot's cycle is given by $\eta = 1 - \frac{T_2}{T_1}$

For η= 1 or 100 %, T_2 = 0 K.

The temperature of 0 K (absolute zero) can not be obtained.

47. **(c)** The working of an air conditioner is similar to the working of a refrigerator. An air conditioner removes heat from the room, does some work and rejects the heat to the surroundings. As air conditioner is put in the middle of the room then due to continuous, external work the room will become slightly warmer.

48. **(b)** $\frac{W}{Q_1} = 1 - \frac{T_2}{T_1} = 1 - \left[\frac{273+27}{273+627}\right] = \frac{2}{3}$; $\therefore W = \frac{2}{3}Q_1 = \frac{2}{3} \times 3000 = 2000\,\text{kcal.} = 8.4 \times 10^6\,J$

49. **(d)** $\eta = 1 - \frac{T_2}{T_1}$ T_1 = T (Temperature of hot reservoir)

For η= 40%, $\frac{40}{100} = 1 - \frac{T_2}{T_1} \Rightarrow \frac{T_2}{T} = \frac{3}{5} \Rightarrow T_2 = \frac{3}{5}T$

For η= 50%, $\frac{50}{100} = 1 - \frac{\frac{3}{5}T}{T_1} \Rightarrow T_1 = \frac{6}{5}T$

50. **(a)** This is a statement of second law of thermodynamics

51. **(b)** Work-done (W) = P_0V_0

According to principle of calorimetry

Heat given = Q_{AB} = Q_{BC}

$= nC_VdT_{AB} + nC_PdT_{BC} = \frac{3}{2}(nRT_B - nRT_A) + \frac{5}{2}(nRT_C - nRT_B)$

$= \frac{3}{2}(2P_0V_0 - P_0V_0) + \frac{5}{2}(4P_0V_0 - 2P_0V_0) = \frac{13}{2}P_0V_0$

Thermal efficiency of engine $(\eta) = \frac{W}{Q_{given}} = \frac{2}{13} = 0.15$

52. **(b)** Efficiency of Carnot engine (η_1)

$= 40\% = 0.4;$

Heat intake = 500 K and

New efficiency $(\eta_2) = 50\ \% = 0.5.$

The efficiency $(\eta) = 1 - \frac{T_2}{T_1}$ or $\frac{T_2}{T_1} = 1 - \eta.$

For first case, $\frac{T_2}{500} = 1 - 0.4$ or $T_2 = 300$ K.

For second case, $\frac{300}{T_1}$

$= 1 - 0.5$ or $T_1 = 600$ K.

53. **(d)** Efficiency, $\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$; $\eta' = 1 - \frac{(T_2 - 100)}{(T_1 - 100)} \times 100 = \left(\frac{T_1 - T_2}{T_1 - 100}\right) \times 100$

Comparing with h we get, the efficiency increases.

54. **(d)** Coefficient of performance,

$Cop = \frac{T_2}{T_1 - T_2}$ $\quad 5 = \frac{273 - 20}{T_1 - (273 - 20)} = \frac{253}{T_1 - 253}$

$5T_1 - (5 \times 253) = 253$; $\qquad 5T_1 = 253 + (5 \times 253) = 1518$

$\therefore T_1 = \frac{1518}{5} = 303.6$ or $T_1 = 303.6 - 273 = 30.6 \cong 31°C$

55. **(d)** Efficiency $\eta = \frac{W_{output}}{Heat_{input}} = \frac{w}{3w} = \frac{1}{3}$; $\qquad \eta = 1 - \frac{Q_2}{Q_1} = \frac{1}{3} \therefore \frac{Q_2}{Q_1} = \frac{2}{3}$

56. **(b)** Given : Q_1 = 1000 J, Q_2 = 600 J

T_1 = 127°C = 400 K, T_2 = ? η = ?

Efficiency of Carnot engine $\qquad \eta = \frac{W}{Q_1} \times 100\%$

or $\eta = \frac{Q_2 - Q_1}{Q_1} \times 100\%$ or, $\eta = \frac{1000 - 600}{1000} \times 100\%$; $\eta = 40\%$

Now, for Carnot cycle $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$; $\frac{600}{1000} = \frac{T_2}{400} \Rightarrow T_2 = \frac{600 \times 400}{1000} = 240K = 240 - 273$; $\therefore T_2 = -33^0C$

57. **(d)** For a Carnot engine, efficiency

$$e = 1 - \frac{T_2}{T_1} = 1 - \frac{127+273}{227+273} = 1 - \frac{400}{500} = \frac{1}{5}$$

Now, $e = \frac{\text{Work output}}{\text{Heat input}} = \frac{W}{6\times10^4}$; $W = e\times6\times10^4 = \frac{1}{5}\times6\times10^4 = 1.2\times10^4$ cal

58. **(c)** $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} \Rightarrow \frac{Q_2}{Q_1} = \frac{T_2}{T_1}$; So, $T_2 = \frac{Q_2 \times T_1}{Q_1} = \frac{150\times500}{300} = 250K$

59. (a) The Carnot cycle consists of the following four processes: A reversible isothermal gas expansion process. In this process, the ideal gas in the system absorbs q in amount heat from a heat source at a high temperature Thigh, expands and does work on surroundings.

60. **(c)** For process to be reversible it must be quasi-static.

For quasi static process all changes take place infinitely slowly. Isothermal process occur very slowly so it is quasi-static and hence it is reversible.

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(a)** Efficiency of ideal heat engine, $\eta = \left(1 - \frac{T_2}{T_1}\right)$

Sink temperature, T_2 = 100°C = 100 + 273 = 373 K

Source temperature, T_1 = 0°C = 0 + 273 = 273 K

Percentage efficiency, $\%\eta = \left(1 - \frac{T_2}{T_1}\right)\times100 = \left(1 - \frac{273}{373}\right)\times100 = \left(\frac{100}{373}\right)\times100 = 26.8\%$

2. **(a)** Gas is monatomic, so $C_p = \frac{5}{2}R$

Given process is isobaric

$\therefore dQ = nC_p dT \Rightarrow dQ = n\left(\frac{5}{2}R\right)dT$

dW = P dV = n RdT

$\therefore$ Required ratio $= \frac{dW}{dQ} = \frac{nRdT}{n\left(\frac{5}{2}R\right)dT} = \frac{2}{5}$

3. **(b)** Using first law of thermodynamics equation,

$\Delta Q = \Delta U + \Delta W$

$\Rightarrow 54 \times 4.18 = \Delta U + 1.013 \times 10^5(167.1 \times 10^{-6} - 0) \Rightarrow \Delta V = 208.7$ J ($\because \Delta W = P\Delta V$)

4. **(a)** Process I volume is constant hence, it is isochoric

In process IV, pressure is constant hence, it is isobaric

5. **(a)** Given, efficiency of engine, $\eta = \frac{1}{10}$

work done on system W = 10J

Coefficient of performance of refrigerator $\beta = \frac{Q_2}{W} = \frac{1-\eta}{\eta} = \frac{1-\frac{1}{10}}{\frac{1}{10}} = \frac{\frac{9}{10}}{\frac{1}{10}} = 9$

Energy absorbed from reservoir

$Q_2 = \beta w$; $Q_2 = 9 \times 10 = 90$ J

6. **(c)** Coefficient of performance of a refrigerator

$$\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$$ (Where Q_2 is heat removed)

Given: $T_2 = 4°C = 4 + 273 = 277$ k

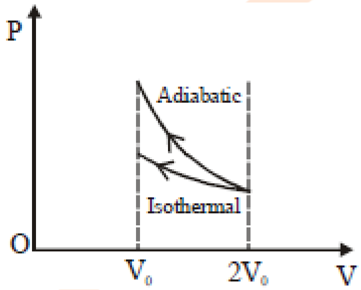
$T_1 = 30°C = 30 + 273 = 303$ k

$$\therefore \beta = \frac{600 \times 4.2}{W} = \frac{277}{303 - 277} \Rightarrow W = 23.65 \text{ joule}$$

Power $P = \frac{W}{t} = \frac{236.5 \text{ joule}}{1 \text{sec}} = 236.5$ watt.

7. **(b)** W_{ext} = negative of area with volume-axis

$W_{(adiabatic)} > W_{(isothermal)}$



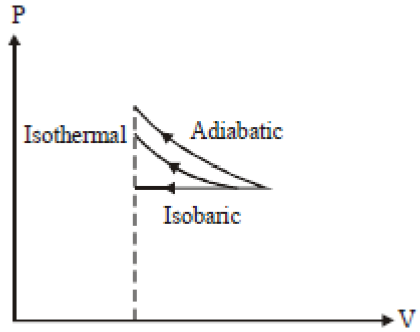
8. **(b)** In cyclic process ABCA

$Q_{cycle} = W_{cycle}$

$Q_{AB} + Q_{BC} + Q_{CA}$ = ar. of Δ ABC

$$+400 + 100 + Q_{C\to A} = \frac{1}{2}(2\times 10^{-3})(4\times 10^{4}) \Rightarrow Q_{C\to A} = -460J \Rightarrow Q_{A\to C} = +460J$$

9. **(d)** Since area under the curve is maximum for adiabatic process so, work done (W = PdV) on the gas will be maximum for adiabatic process



10. **(d)** Coefficient of performance,

$$Cop = \frac{T_2}{T_1 - T_2}$$

$$5 = \frac{273 - 20}{T_1 - (273 - 20)} = \frac{253}{T_1 - 253}$$

$$5T_1 - (5 \times 253) = 253$$
$$5T_1 = 253 + (5 \times 253) = 1518$$

$$\therefore T_1 = \frac{1518}{5} = 303.6$$

or, $T_1 = 303.6 - 273 = 30.6 \cong 31°C$

11. **(c)** For isothermal process $P_1V_1 = P_2V_2$

$\Rightarrow PV = P_2(2V) \Rightarrow P_2 = \frac{P}{2}$

For adiabatic process

$P_2V_2^{\gamma} = P_3V_3^{\gamma}$

$\Rightarrow \left(\frac{P}{2}\right)(2v)^{\gamma} = P_3 16v)^{\gamma} \Rightarrow P_3 = \frac{3}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{64}$

12. **(d)** Work done by the system in the cycle

= Area under P-V curve and V-axis

$$= \frac{1}{2}(2P_0 - P_0)(2V_0 - V_0) + \left[-\left(\frac{1}{2}\right)(3P_0 - 2P_0)(2V_0 - V_0)\right] = \frac{P_0V_0}{2} - \frac{P_0V_0}{2} = 0$$

13. (2) Adiabatic process $\Delta Q = 0$

14. (2) $Q = \Delta U + W$

$\Rightarrow mL = \Delta U + P(V_2 - V_1) \Rightarrow 1(2256) = \Delta U + 1\times 10^5 (1670\times 10^{-6}) \Rightarrow \Delta U = 2089\,J$

15. (2) the temperatures of the source and sink

Efficiency of carnot engine

T_1 = temperature of source

T_2 = temperature of sink

16. (3) P = constant $\Rightarrow$ Isobaric process

17. (2)For sphere $M = \frac{4}{3}\pi r^3 \rho \Rightarrow M \propto r^3 \Rightarrow \frac{M_1}{M_2} = \left(\frac{r_1}{r_2}\right)^3$

As $Q = MS\Delta\theta$, for same value of S and $\Delta\theta$

$Q \propto M \Rightarrow \frac{Q_1}{Q_2} = \frac{M_1}{M_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{3}{2}\right)^3 = \frac{27}{8}$

18. (3) It is expanded against vacuum, so dW = 0

The entire system is thermally insulated. So dQ = 0

$dT = 0 \Rightarrow T_f - T_i = 0 \Rightarrow T_i = T_f$

But intermediate temperature is not constant. Hence free expansion is not isothermal. Since the expansion quick in a thermally isolated system, it is adiabatic expansion

19. Adiabatic curve is more steeper