Chapter 12
Thermodynamics

THERMAL EQUILIBRIUM AND ZEROTH LAW OF THERMODYNAMICS

Thermal Equilibrium

Two systems are said to be in thermal equilibrium with each other if they have the same temperature.

Zeroth Law of Thermodynamics

If objects A and B are separately in thermal equilibrium with a third object C then objects A and B are in thermal equilibrium with each other.

FIRST LAW OF THERMODYNAMICS

First law of thermodynamics gives a relationship between heat, work and internal energy.

(a) **Heat :** *It is the energy which is transferred from a system to surrounding or vice-versa due to temperature difference between system and surroundings.*
- (i) It is a macroscopic quantity.
- (ii) It is path dependent i.e., it is not point function.
- (iii) If system liberates heat, then by sign convention it is taken negative, If system absorbs heat, it is positive.

(b) **Work :** *It is the energy that is transmitted from one system to another by a force moving its points of application.* The expression of work done on a gas or by a gas is

$$W = \int dW = \int_{V_1}^{V_2} PdV$$

where V_1 is volume of gas in initial state and V_2 in final state.
- (i) It is also macroscopic and path dependent function.
- (ii) By sign convention it is +ive if system does work (i.e., expands against surrounding) and it is – ive, if work is done on system (i.e., contracts).
- (iii) In cyclic process the work done is equal to area under the cycle and is negative if cycle is anti-clockwise and +ive if cycle is clockwise (shown in fig.(a) and (b)).

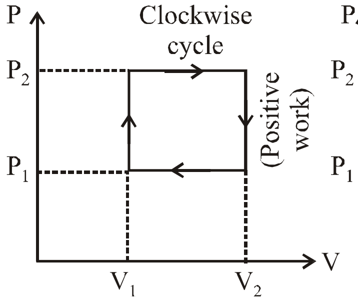


Fig: (a)

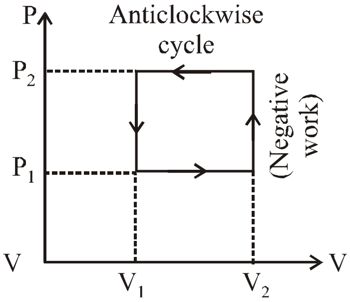


Fig: (b)

(c) **Internal energy :** *The internal energy of a gas is sum of internal energy due to moleculer motion (called internal kinetic energy U_K) and internal energy due to molecular configuration (called internal potential energy $U_{P.E.}$)*

i.e., $U = U_K + U_{P.E.}$ ……(1)

- (i) In ideal gas, as there is no intermolecular attraction, hence

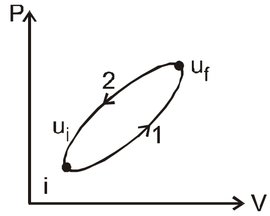
$$U = U_K = \frac{3n}{2}RT \qquad \text{……(2)}$$

(for *n* mole of ideal gas)

- (ii) Internal energy is path independent i.e., point function.
- (iii) In cyclic process, there is no change in internal energy (shown in fig.)

i.e., $dU = U_f - U_i = 0$

$\Rightarrow U_f = U_i$



- (iv) Internal energy of an ideal gas depends only on temperature eq.(2).

First law of thermodynamics is a generalisation of the law of conservation of energy that includes possible change in internal energy.

First law of thermodynamics *"If certain quantity of heat dQ is added to a system, a part of it is used in increasing the internal energy by dU and a part is use in performing external work done dW*

$$i.e.,\ dQ = dU + dW \Rightarrow dU = dQ - dW$$

The quantity dU (i.e., $dQ - dW$) is path independent but dQ and dW individually are not path independent.

Applications of First Law of Thermodynamics

(i) In **isobaric process** P is constant

so $dW = \int_{V_1}^{V_2} PdV = P(V_2 - V_1)$

so $dQ = dU + dW = n\,C_P\,dT$

(ii) In **cyclic process** heat given to the system is equal to work done (area of cycle).

(iii) In **isothermal process** temperature T is constant and work done is

$$dW = \int_{V_1}^{V_2} PdV = nRT \, Log_e \frac{V_2}{V_1}$$

Since, T = constant so for ideal gas dU = 0

Hence, $dQ = dW = nRT \; Log_e \frac{V_2}{V_1}$ (for ideal gas)

(iv) In **isochoric process** W = 0 as V = constant
It means that heat given to system is used in increasing internal energy of the gas.

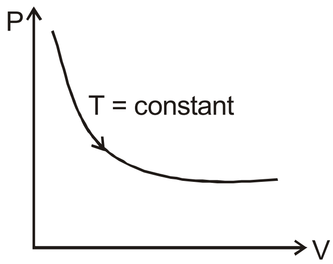
(v) In **adiabatic process** heat given or taken by system from surrounding is zero i.e., dQ = 0

$$dU = -dW = -\left[\frac{nR}{\gamma-1}(T_1 - T_2)\right] = \left[\frac{(P_1V_1 - P_2V_2)}{\gamma - 1}\right]$$

It means that if system expands dW is +ive and dU is –ive (i.e., temperature decrease) and if system contracts dW is –ive and dU is +ive (i.e., temperature increase).

THERMODYNAMIC PROCESSES

(i) ***Isothermal process :*** *If a thermodynamic system is perfectly conducting to surroundings and undergoes a physical change in such a way that temperature remains constant throughout, then process is said to be isothermal process.*

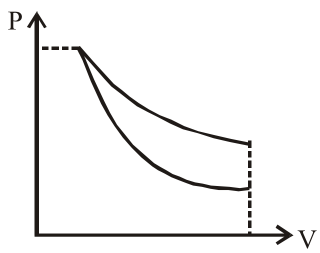


For isothermal process, the equation of state is
PV = nRT = constant, where n is no. of moles.
For ideal gas, since internal energy depends only on temperature.

$$dU = 0 \Rightarrow dQ = dW = \int_{V_1}^{V_2} PdV = nRT \int_{V_1}^{V_2} \frac{dV}{V}$$

or $dQ = nRT \, \log_e \frac{V_2}{V_1} = 2.303 nRT \, \log_{10} \frac{V_2}{V_1}$

(ii) ***Adiabatic process :*** *If system is completely isolated from the surroundings so that no heat flows in or out of it, then any change that the system undergoes is called an adiabatic process.*



For ideal gas, dQ = 0
$dU = \mu C_V dT$ (for any process)

$$dW = \int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} \frac{K}{V^\gamma} dV$$

(where $PV^\gamma = K$ = constant)

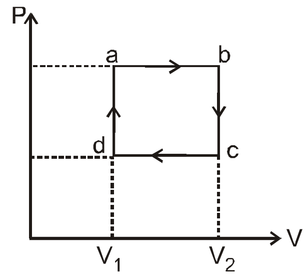
$$= \frac{K}{1-\gamma}\left(\frac{1}{V_2^{\gamma-1}} - \frac{1}{V_1^{\gamma-1}}\right) = \frac{(P_2V_2 - P_1V_1)}{1-\gamma}$$

where PV^γ = constant is applicable only in adiabatic process. Adiabatic process is called isoentropic process (in these process entropy is constant).

(iii) ***Isobaric process :*** *A process taking place at constant pressure is called an isobaric process.* In this process $dQ = n \, C_p dT$, $dU = n \, C_V dT$ and $dW = P(V_2 – V_1)$

(iv) ***Isochoric process :*** *A process taking place at constant volume is called isochoric process.*
In this process, $dQ = dU = n \, C_V dT$ and dW = 0

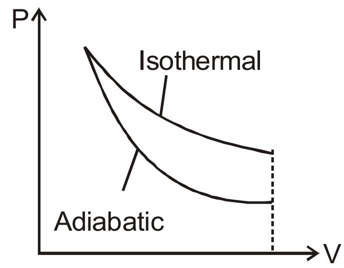
(v) ***Cyclic process :*** *In this process the inital state and final state after traversing a cycle (shown in fig.) are same.*
In cyclic process, $dU = 0 = U_f – U_i$ and dW = area of cycle = area (abcd)



Slope of adiabatic and isothermal curve :

For isothermal process PV = constant
On differentiating, we get PdV + VdP = 0
And slope of isothermal curves

$$\left(\frac{dP}{dV}\right)_{isothermal} = -\frac{P}{V} \quad ...(1)$$



For adiabatic process PV^γ = constant
On differentiation, we get slope of adiabatic curve

$$\left(\frac{dP}{dV}\right)_{adiabatic} = -\gamma(P/V) \quad ....(2)$$

It is clear from equation (1) and (2) that *the slope of adiabatic curve is more steeper than isothermal curve as shown by fig by γ time ($\gamma = C_P/C_V$)*

Graphs of thermodynamic processes :

1. In the figure (i) P–V graph the process ab is isothermal, bc is isobaric and ca is isochoric.

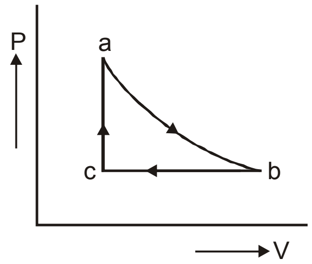


Fig (i)

The fig (ii) is the P–T diagram of fig (i)

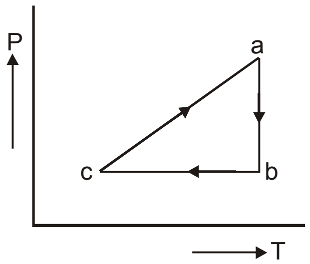
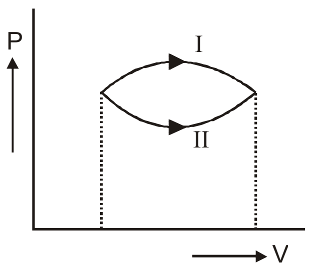


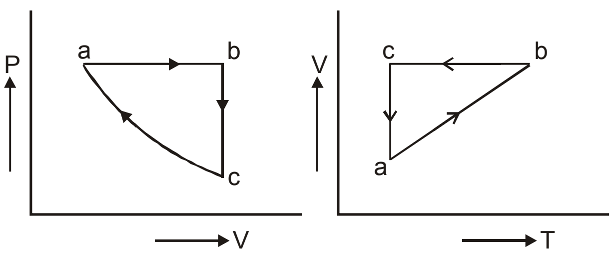
Fig.(ii)

2. Figure below shows P – V diagrams for two processes.

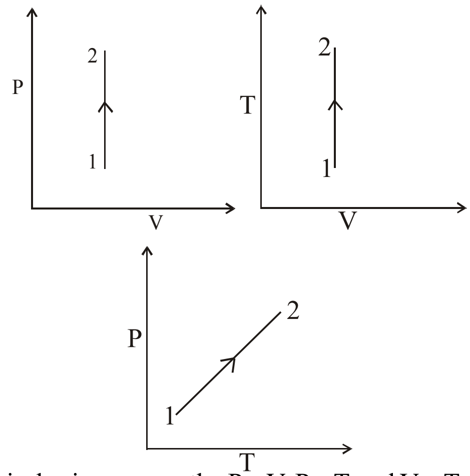


The heat absorbed in process I is more than that in II. Because, area under process I is also more than area under process II. The work done in the process I is more than that in II. Also, the change in internal energy is same in both cases.

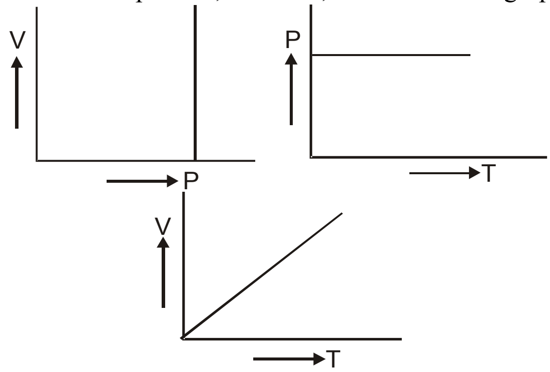
3. The P–V and corresponding V–T diagram for a cyclic process abca on a sample of constant mass of ideal gas are shown below:



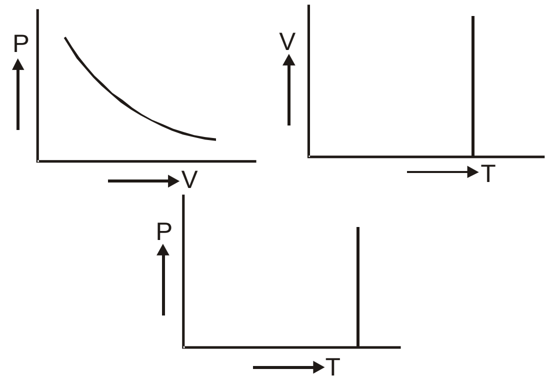
4. For isochoric process, the P–V, V–T and P–T graphs :



5. For isobaric process, the P – V, P – T and V – T graphs :



6. For isothermal process, the P – V, V – T and P – T graphs :



Keep in Memory

1. In thermodynamics heat and work are not state variables, whereas internal energy is a state variable.
2. For ideal-gas
   (i) *relation between P and V is* PV^{γ} = *constant*
   (ii) *relation between V and T is* $TV^{\gamma-1}$ = *constant*
   (iii) *relation between P and T is* $T^{\gamma}P^{1-\gamma}$ = *constant*
3. A quasi-static process is an infinitely slow process such that system remains in thermal and mechanical equilibrium with the surroundings throughout.
4. Pressure, volume, temperature and mass are state variables. Heat and work are not state variables.
5. A graphical representation of the state of a system with the help of two thermodynamical variables is called **indicator diagram**.

REVERSIBLE AND IRREVERSIBLE PROCESS

Reversible Process :

A process which can proceed in opposite direction in such a way that the system passes through the same states as in direct process and finally the system and the surroundings acquire the intial conditions.

Conditions for a process to be reversible :

(a) The process must be extremely slow.

(b) There should no loss of energy due to conduction, or radiation. The dissipating forces should not be in the system.

(c) The system must always be in thermal and chemical equilibrium with the surroundings.

Examples : Fusion of ice, vaporisation of water, etc.

Irreversible Process :

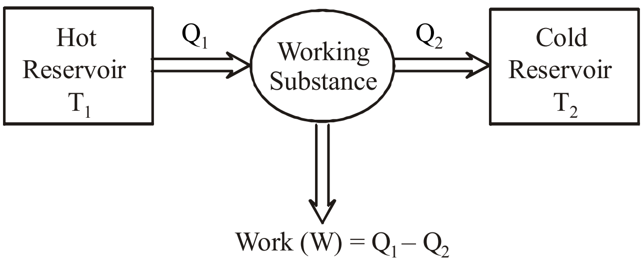
The process which cannot be traced back in the opposite direction is defined as irreversible process.

Examples : Work done against friction, magnetic hysteresis.

- In nature all process are irreversible, because no natural process can fulfil the requirement of a reversible process.

HEAT ENGINE

A heat engine is a device which converts heat energy into mechanical energy.



Efficiency of heat engine is given by

$$\text{Efficiency } \eta = \frac{\text{Work done } (W)}{\text{Heat taken from source } (T_1)}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$

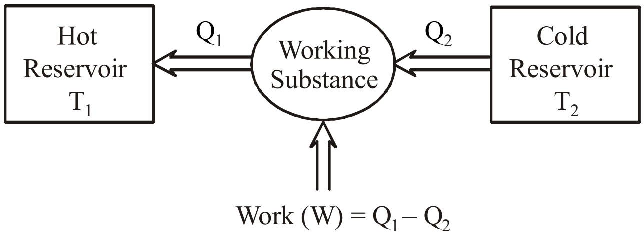
where Q_2 = amount of heat rejected per cycle to the sink (of temp T_2)

Q_1 = amount of heat energy absorbed per cycle from the source (of temp T_1).

The efficiency of heat engine η is never greater than unity, $\eta = 1$ only for ideal engine & for practical heat engine $\eta < 1$.

REFRIGERATOR AND HEAT PUMP :

Refrigerator or heat pump is a heat engine running in backward direction i.e. working substance (a gas) takes heat from a cold body and gives out to a hotter body with the use of external energy i.e. electrical energy. A heat pump is the same as a refrigerator.



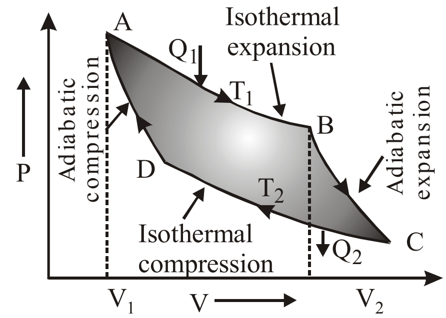
The coefficient of performance of refrigerator or heat pump is

$$\beta = \frac{\text{Heat extracted from cold reservoir}}{\text{Work done on refrigerator}} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2},$$

where T_2 is temperature of cold body and T_1 is temperature of hot body.

CARNOT ENGINE

Carnot devised an ideal engine which is based on a reversible cycle of four operations in succession : *isothermal expansion, adiabatic expansion, isothermal compression and adiabatic compression.*



Efficiency of Carnot engine,

$$\eta = \frac{W}{Q_1} = \frac{\mu R T_1 \, In\left(\frac{V_2}{V_1}\right) + \mu R T_2 \, In\left(\frac{V_4}{V_3}\right)}{\mu R T_1 \, In\left(\frac{V_2}{V_1}\right)}$$

The points B and C are connected by an adiabatic path as are the points D and A. Hence, using this eq^n. and the adiabatic gas eq^n.

$T_1 V_2^{(\gamma - 1)} = T_2 V_3^{(\gamma - 1)}$ and $T_1 V_1^{(\gamma - 1)} = T_2 V_4^{(\gamma - 1)}$.

Combination of the above eq^{n}s. gives $\frac{V_2}{V_1} = \frac{V_3}{V_4}$, and,

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

or, $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$.

The percentage efficiency of Carnot's engine,

$$\eta = \frac{T_1 - T_2}{T_1} \times 100\% \text{ or, } \eta = \frac{Q_1 - Q_2}{Q_1} \times 100\%$$

The efficiency of a Carnot engine is never 100% because it is 100% only if temperature of sink $T_2 = 0$ which is impossible.

In a Carnot cycle, $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$ or $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$.

Carnot Theorem : *No irreversible engine (I) can have efficiency greater than Carnot reversible engine (R) working between same hot and cold reservoirs.*

i.e., $\eta_R > \eta_I$ or $1 - \frac{T_2}{T_1} > 1 - \frac{Q_2}{Q_1}$

SECOND LAW OF THERMODYNAMICS

It states that *it is impossible for a self acting machine unaided by any external agency, to transfer heat from a body at a lower temperature to a body at higher temperature.*

It is deduced from this law that the efficiency of any heat engine can never be 100%.

Entropy :

Entropy is a measure of disorder of the molecular motion of a system. The greater the disorder, the greater is the entropy. The change in entropy is given by

$$\Delta S = \frac{\text{Heat absorbed by the system } (dQ)}{\text{Absolute temperature } (T)}$$

$S_1 - S_2 = \int \frac{dQ}{T}$ (here T is not differentiable)

Clausius inequality

$$\oint \frac{dQ}{T} \le 0 \quad \text{or,} \quad dS \ge \int \frac{dQ}{T}$$

or, $dQ = TdS \ge dU + PdV$

Also, $S = K \log_e \omega$

$\Delta S = K \log_e \frac{\omega_2}{\omega_1}$ is the microscopic form of entropy, where

K is Boltzmann's constant and ω respresents the number of possible microscopic states.

Energy entering a body increases disorder.

Energy leaving a body decreases disorder.

When a hot body is brought into thermal contact with a cold body for a short time, then :

(i) Each body will experience a change in the entropy of its particle.

(ii) The hot body experiences a decrease in entropy (a negative change) of magnitude

$$\Delta S_1 = \frac{\Delta Q}{T_1}$$

(iii) The cold body experiences an increase in entropy (a positive change) of magnitude

$$\Delta S_2 = \frac{\Delta Q}{T_2}$$

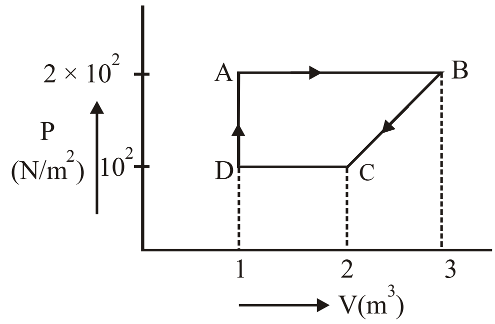
(iv) The net change in entropy

$$\Delta S = \Delta S_1 + \Delta S_2$$

The effect of naturally occurring processes is always to increase the total entropy (or disorder) of the universe.

Example 1.

A cyclic process is shown in fig. Work done during isobaric expansion is



(a) 1600 J (b) 100 J

(c) 400 J (d) 600 J

Solution : **(c)**

Isobaric expansion is represented by curve AB;

Work done = area under AB

$= 2 \times 10^2 \times (3 - 1) = 4 \times 10^2 = 400$ J.

Example 2.

An ideal gas heat engine operates in carnot cycle between 227ºC and 127ºC. It absorbs 6×10^4 cal of heat at higher temp. Amount of heat converted into work is

(a) 1.2×10^4 cal (b) 2.4×10^4 cal

(c) 6×10^4 cal (d) 4.8×10^4 cal

Solution **: (a)**

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

$$\therefore \frac{Q_2}{6 \times 10^4} = \frac{127 + 273}{227 + 273} = \frac{400}{500} \quad \left(\text{As } \eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}\right)$$

$$Q_2 = \frac{4}{5} \times 6 \times 10^4 = 4.8 \times 10^4 \; cal$$

$$\therefore \; W = Q_1 - Q_2 = 6 \times 10^4 - 4.8 \times 10^4 = 1.2 \times 10^4 \text{ cal.}$$

Example 3.

An ideal carnot engine whose efficiency is 40% receives heat at 500 K. If its efficiency were 50%, then what would be intake temp. for same exhaust temp ?

Solution :

From, $\eta = 1 - \frac{T_2}{T_1}$; $\frac{T_2}{T_1} = 1 - \eta = 1 - \frac{40}{100} = \frac{3}{5}$;

$$\therefore \; T_2 = \frac{3}{5} T_1 = \frac{3}{5} \times 500 = 300\,K$$

Again $\frac{T_2}{T_1'} = 1 - \eta'$ or $\frac{300}{T_1'} = 1 - \frac{50}{100} = \frac{1}{2}$

or $T_1' = 600\,K$

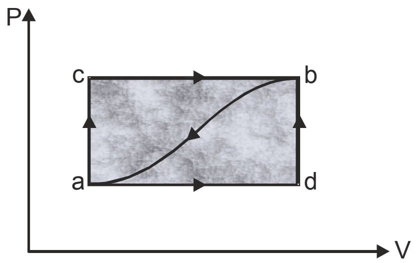
Example 4.

When a system is taken from state a to state b, in fig. along the path $a \to c \to b$, 60 J of heat flow into the system, and 30 J of work are done :

(i) How much heat flows into the system along the path $a \to d \to b$ if the work is 10 J.

(ii) When the system is returned from b to a along the curved path, the work done by the system is –20 J. Does the system absorb or liberate heat, and how much?

(iii) If, $U_a = 0$ and $U_d = 22$ J, find the heat absorbed in the process $a \to d$ and $d \to b$.



Solution :

For the path $a \to c \to b$

$dU = dQ - dW = 60 - 30 = 30$ J or $U_b - U_a = 30$ J

(i) Along the path $a \to d \to b$

$dQ = dU + dW = 30 + 10 = 40$ J

(ii) Along the curved path b – a

$dQ = (U_a - U_b) + W = (-30) + (-20) = -50$ J,

heat flows out the system

(iii) $Q_{ad} = 32$ J; $Q_{db} = 8$ J

Example 5.

Two samples of a gas initially at same temperature and pressure are compressed from a volume V to V/2. One sample is compressed isothermally and the other adiabatically. In which sample is the pressure greater?

Solution :

Let initial volume, $V_1 = V$ and final volume, $V_2 = V/2$

Initial pressure, $P_1 = P$; final pressure, $P_2 = ?$

For isothermal compression

$$P_2V_2 = P_1V_1 \text{ or } P_2 = \frac{P_1V_1}{V_2} = \frac{PV}{V/2} = 2P$$

For adiabatic compression

$$P_2'V_2^\gamma = P_1V_1^\gamma \text{ or } P_2' = P_1\left(\frac{V_1}{V_2}\right)^\gamma = P\left(\frac{V}{V/2}\right)^\gamma$$

or $P_2' = 2^\gamma P$

Since $\gamma > 1 \quad \therefore 2^\gamma > 2 \therefore P_2' > P_2$

Pressure during adiabatic compression is greater than the pressure during isothermal compression.

Example 6.

A Carnot engine working between 300 K and 600 K has a work output of 800 J per cycle. What is the amount of heat energy supplied to the engine from source per cycle?

Solution :

$W = 800$ J, $T_1 = 600$ K, $T_2 = 300$ K

$$\therefore \quad \eta = 1 - \frac{T_1}{T_2} = \frac{W}{Q_1} = 1 - \frac{300}{600} = \frac{800}{Q_1} \text{ or } 0.5 = \frac{800}{Q_1}$$

Heat energy supplied by source,

$$Q = \frac{800}{0.5} = 1600 \text{ joule per cycle}$$

Example 7.

The temperatures T_1 and T_2 of the two heat reservoirs in an ideal Carnot engine are 1500°C and 500°C respectively. Which of the following : increasing T_1 by 100°C or decreasing T_2 by 100°C would result in a greater improvement in the efficiency of the engine?

Solution :

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

Given $T_1 = 1500°C = 1500 + 273 = 1773$ K and

$T_2 = 500°C = 500 + 273 = 773$ K.

When the temperature of the source is increased by 100°C, keeping T_2 unchanged, the new temperature of the source is

$T'_1 = 1500 + 100 = 1600°C = 1873$ K. The efficiency becomes

$$\eta' = 1 - \frac{T_2}{T'_1} = 1 - \frac{773}{1873} = 0.59$$

On the other hand, if the temperature of the sink is decreased by 100°C, keeping T_1 unchanged, the new temperature of the sink is $T'_2 = 500 - 100 = 400°C = 673$ K. The efficiency now becomes

$$\eta'' = 1 - \frac{T'_2}{T_1} = 1 - \frac{673}{1773} = 0.62$$

Since η'' is greater than η', decreasing the temperature of the sink by 100°C results in a greater efficiency than increasing the temperature of the source by 100°C.

Example 8.

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 N/m^2 and 6 litre respectively. The final volume of the gas is 2 litres. Molar specific heat of the gas at constant volume is 3R/2. [$(3)^{5/3} = 6.19$]

Solution :

For an adiabatic change PV^γ = constant

$$P_1V_1^\gamma = P_2V_2^\gamma$$

As molar specific heat of gas at constant volume

$$C_v = \frac{3}{2}R$$

$$C_P = C_V + R = \frac{3}{2}R + R = \frac{5}{2}R\ ;$$

$$\gamma = \frac{C_P}{C_V} = \frac{(5/2)\,R}{(3/2)\,R} = \frac{5}{3}$$

$$\therefore \text{ From eq}^n.\ (1)\ P_2 = \left(\frac{V_1}{V_2}\right)^{\gamma} P_1 = \left(\frac{6}{2}\right)^{5/3} \times 10^5\ \text{N/m}^2$$

$$= (3)^{5/3} \times 10^5 = 6.19 \times 10^5\ \text{N/m}^2$$

$$\text{Work done} = \frac{1}{1-\left(\frac{5}{3}\right)}[6.19\times10^5 \times 2\times10^{-3} - 10^{-5}\times 6\times10^{-3}]$$

$$= -\left[\frac{2\times10^2\times3}{2}(6.19-3)\right]$$

$$= -3 \times 10^2 \times 3.19 = -957\ \text{joule}$$

[–ve sign shows external work done on the gas]

Example 9.

A refrigerator is to maintain eatables kept inside at 90C. If room temperature is 360C, calculate the coefficient of performance.

Solution :

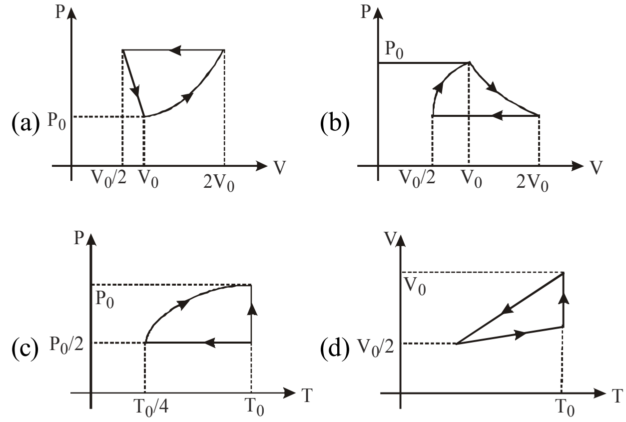
Here, $T_1 = 36°C = 36 + 273 = 309\ K$,

$T_2 = 10°C = 10 + 273 = 283\ K$

$$\text{COP} = \frac{T_2}{T_1 - T_2} = \frac{283}{309-283} = \frac{283}{26} = 10.9$$

Example 10.

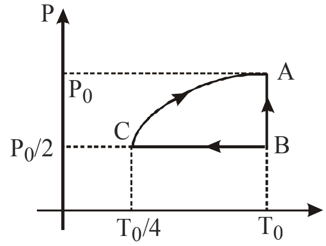
One mole of an ideal gas at pressure P_0 and temperature T_0 is expanded isothermally to twice its volume and then compressed at constant pressure to $(V_0/2)$ and the gas is brought back to original state by a process in which $P \propto V$ (Pressure is directly proportional to volume). The correct representation of process is



Solution : (c)

Process AB is isothermal expansion,
BC is isobaric compression and in process CA

$$P \propto \frac{nRT}{P} \Rightarrow P^2 \propto T$$



Example 11.

A Carnot's heat engine works with an ideal monatomic gas, and an adiabatic expansion ratio 2. Determine its efficiency.

Solution :

Given, $\rho = \frac{V_3}{V_2} = 2$ and γ for a monatomic gas = 5/3.

Using, $\eta = 1 - \left(\frac{1}{\rho}\right)^{\gamma - 1}$

we have, the required efficiency

$$\eta = 1 - \left(\frac{1}{2}\right)^{\frac{5}{3}-1} = 1 - 0.63 = 0.37 \text{ or } 37\%$$

CONCEPT MAP

THERMODYNAMICS
The branch of science deals with the concepts of heat and temperature and their interconversion

Laws of thermodynamics

Zeroth law of thermodynamics
Two systems A and B are in thermal equilibrium with a third system C, then A and B are in thermal equilibrium with each other.

Thermal equilibrium
Two systems are in thermal equilibrium with each other if they have the same temperature.

Thermodynamic state variable
(i) Extensive - indicate the size of the system e.g. U, volume, total mass
(ii) Intensive - do not indicate size of the system e.g., pressure and temperature

First law of thermodynamics
$\Delta Q = \Delta U + \Delta W$ $(\Delta W = P\Delta V)$ It is a statement of law of conservation of energy

Second law of thermodynamics
It is impossible for an engine working between a cyclic process to extract heat from a reservoir and convert completely into work.

Entropy(S) – A measure of molecular disorder of a system.
Change in entropy $\delta S = \frac{\delta Q}{T}$

Specific heat capacity
$C = \frac{\Delta Q}{m(\Delta T)}$
$C_P - C_V = R$ (**Mayer's formula**)

Thermodynamic processes

Quasi – static process
Infinitely slow process such that system remains in thermal and mechanical equilibrium with the surroundings throughout

In Quasi – static process,
The pressure (P) and temperature (T) of the environment can differ from those of the system only infinitesimally

Reversible and Irreversible process
Any process made to proceed in the reverse direction by variation in its conditions – Reversible process.
Any process that cannot be retraced in the reverse direction exactly – Irreversible process.

Carnot's Engine
An Ideal engine works on a reversible cycle of four operations in succession –
(i) isothermal expansion, (ii) adiabatic expansion, (iii) isothermal compression and (iv) adiabatic compression.
Efficiency of carnot's engine $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

Isothermal process
Temperature = Constant
PV = Constant = n RT
$W = \int_{V_1}^{V_2} \frac{nRT}{V} dV$

Adiabatic process
A thermally insulated system, neither gains nor loses heat
PV^{γ} = constant
$TV^{\gamma-1}$ = constant
$\frac{P^{\gamma-1}}{T^{\gamma}}$ = constant $C_p/C_V = \gamma$

Isochoric process
Volume remains constant
$\frac{P}{T}$ = constant
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Isobaric process
Pressure remains constatnt
$\frac{V}{T}$ = constant
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Cyclic Process
In this process, system returns to initial state
For a cyclic process $\Delta U = 0$

Heat engine
Converts continuously heat into mechanical energy in cyclic process. Efficiency
$\eta = \frac{W}{Q} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

Refrigerator and Heat pump
Refrigerator is a heat engine working in the reverse direction. Coefficient of performance,
$\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$

EXERCISE - 1
Conceptual Questions

1. Which of the following is incorrect regarding first law of thermodynamics?
(a) It is a restatement of principle of conservation of energy.
(b) It is applicable to cyclic processes
(c) It introduces the concept of entropy
(d) It introduces the concept of internal energy

2. Choose the incorrect statement related to an isobaric process.
(a) $\frac{V}{T}$ = constant
(b) $W = P\Delta V$
(c) Heat given to a system is used up in raising the temperature only.
(d) $\Delta Q > W$

3. The internal energy of an ideal gas does not depend upon
(a) temperature of the gas
(b) pressure of the gas
(c) atomicity of the gas
(d) number of moles of the gas.

4. During isothermal expansion, the slope of P-V graph
(a) decreases (b) increases
(c) remains same (d) may increase or decrease

5. During melting of ice, its entropy
(a) increases (b) decreases
(c) remains same (d) cannot say

6. Which of the following processes is adiabatic ?
(a) Melting of ice
(b) Bursting of tyre
(c) Motion of piston of an engine with constant speed
(d) None of these

7. At a given temperature the internal energy of a substance
(a) in liquid state is equal to that in gaseous state.
(b) in liquid state is less than that in gaseous state.
(c) in liquid state is more than that in gaseous state.
(d) is equal for the three states of matter.

8. Air conditioner is based on the principle of
(a) Carnot cycle
(b) refrigerator
(c) first low of thermodynamics
(d) None of these

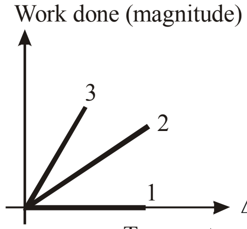
9. A mass of ideal gas at pressure P is expanded isothermally to four times the original volume and then slowly compressed adiabatically to its original volume. Assuming γ to be 1.5, the new pressure of the gas is
(a) 2 P (b) P
(c) 4 P (d) P/2

10. One mole of an ideal gas at temperature T was cooled isochorically till the gas pressure fell from P to $\frac{P}{n}$. Then, by an isobaric process, the gas was restored to the initial temperature. The net amount of heat absorbed by the gas in the process is
(a) nRT (b) $\frac{RT}{n}$
(c) RT $(1 - n^{-1})$ (d) RT $(n - 1)$

11. Ice contained in a beaker starts melting when
(a) the specific heat of the system is zero
(b) internal energy of the system remains constant
(c) temperature remains constant
(d) entropy remains constant

12. A uniform sphere is supplied heat electrically at the centre at a constant rate. In the steady state, steady temperatures are established at all radial locations r; heat flows outwards radial and is ultimately radiated out by the outer surface isotropically. In this steady state, the temperature gradient varies with radial distance r according to
(a) r^{-1} (b) r^{-2}
(c) r^{-3} (d) $r^{-3/2}$

13. For an ideal gas graph is shown for three processes. Process 1, 2 and 3 are respectively.



(a) Isobaric, adiabatic, isochoric
(b) Adiabatic, isobaric, isochoric
(c) Isochoric, adiabatic, isobaric
(d) Isochoric, isobaric, adiabatic

14. The efficiency of carnot engine when source temperature is T_1 and sink temperature is T_2 will be
(a) $\frac{T_1 - T_2}{T_1}$ (b) $\frac{T_2 - T_1}{T_2}$
(c) $\frac{T_1 - T_2}{T_2}$ (d) $\frac{T_1}{T_2}$

15. In the equation PV^{γ} = constant, the value of γ is unity. Then the process is
(a) isothermal (b) adiabatic
(c) isobaric (d) irreversible

16. For adiabatic processes (Letters have usual meanings)
(a) $P^{\gamma}V$ = constant (b) $T^{\gamma}V$ = constant
(c) $TV^{\gamma-1}$ = constant (d) TV^{γ} = constant

17. The gas law $\frac{PV}{T}$ = constant is true for
(a) isothermal changes only
(b) adiabatic changes only
(c) both isothermal and adiabatic changes
(d) neither isothermal nor adiabatic change

18. When heat is given to a gas in an isothermal change, the result will be
(a) external work done
(b) rise in temperature
(c) increase in internal energy
(d) external work done and also rise in temperature

19. Volume of one mole gas changes according to the V = a/T. If temperature change is ΔT, then work done will be
(a) $R\Delta T$ (b) $-R\Delta T$
(c) $\frac{R}{\gamma-1}\Delta T$ (d) $R(\gamma-1)\Delta T$

20. In changing the state of thermodynamics from A to B state, the heat required is Q and the work done by the system is W. The change in its internal energy is
(a) $Q+W$ (b) $Q-W$
(c) Q (d) $\frac{Q-W}{2}$

21. If ΔQ and ΔW represent the heat supplied to the system and the work done on the system respectively, then the first law of thermodynamics can be written as
(a) $\Delta Q = \Delta U + \Delta W$ (b) $\Delta Q = \Delta U - \Delta W$
(c) $\Delta Q = \Delta W - \Delta U$ (d) $\Delta Q = -\Delta W - \Delta U$

22. The work done in which of the following processes is equal to the internal energy of the system?
(a) Adiabatic process (b) Isothermal process
(c) Isochoric process (d) None of these

23. Which of the following processes is reversible?
(a) Transfer of heat by conduction
(b) Transfer of heat by radiation
(c) Isothermal compression
(d) Electrical heating of a nichrome wire

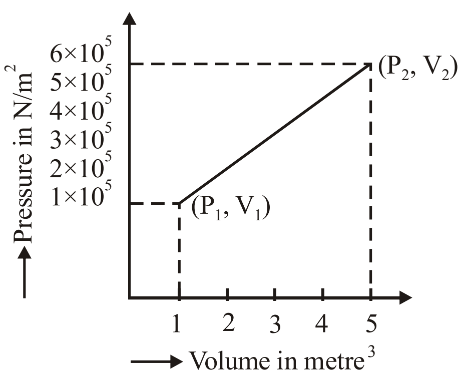
24. In thermodynamic processes which of the following statements is not true?
(a) In an isochoric process pressure remains constant
(b) In an isothermal process the temperature remains constant
(c) In an adiabatic process PV^{γ} = constant
(d) In an adiabatic process the system is insulated from the surroundings

25. Monatomic, diatomic and polyatomic ideal gases each undergo slow adiabatic expansions from the same initial volume and same initial pressure to the same final volume. The magnitude of the work done by the environment on the gas is
(a) the greatest for the polyatomic gas
(b) the greatest for the monatomic gas
(c) the greatest for the diatomic gas
(d) the question is irrelevant, there is no meaning of slow adiabatic expansion

EXERCISE - 2
Applied Questions

1. A gas at 27ºC and pressure of 30 atm. is allowed to expand to atmospheric pressure and volume 15 times larger. The final temperature of the gas is
(a) – 123ºC (b) +123ºC
(c) 273ºC (d) 373ºC

2. A system changes from the state (P_1, V_1) to (P_2, V_2) as shown in the figure. What is the work done by the system?



(a) 7.5×10^5 joule (b) 7.5×10^5 erg
(c) 12×10^5 joule (d) 6×10^5 joule

3. A refrigerator works between 0ºC and 27ºC. Heat is to be removed from the refrigerated space at the rate of 50 kcal/minute, the power of the motor of the refrigerator is
(a) 0.346 kW (b) 3.46 kW
(c) 34.6 kW (d) 346 kW

4. A perfect gas goes from a state A to another state B by absorbing 8×10^5 J of heat and doing 6.5×10^5 J of external work. It is now transferred between the same two states in another process in which it absorbs 10^5 J of heat. In the second process
(a) work done by gas is 10^5 J
(b) work done on gas is 10^5 J
(c) work done by gas is 0.5×10^5 J
(d) work done on the gas is 0.5×10^5 J

5. 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

(a) 8 joule per K (b) 0.8 joule per K
(c) 4.0 joule per K (d) 0.4 joule per K

6. A polyatomic gas ($\gamma = 4/3$) is compressed to 1/8th of its volume adiabatically. If its initial pressure is P_0, its new pressure will be

(a) $8P_0$ (b) $16P_0$
(c) $6P_0$ (d) $2P_0$

7. The efficiency of a Carnot engine operating with reservoir temperatures of 100ºC and –23ºC will be

(a) $\frac{100+23}{100}$ (b) $\frac{100-23}{100}$
(c) $\frac{100+23}{373}$ (d) $\frac{100-23}{373}$

8. By what percentage should the pressure of a given mass of a gas be increased so as to decrease its volume by 10% at a constant temperature?

(a) 8.1 % (b) 9.1 %
(c) 10.1 % (d) 11.1 %

9. A gas has pressure P and volume V. It is now compressed adiabatically to 1/32 times the original volume. Given that $(32)^{1.4} = 128$, the final pressure is ($\gamma = 1.4$)

(a) P/128 (b) P/32
(c) 32 P (d) 128 P

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

(a) 450 K (b) 300 K
(c) –142ºC (d) 327ºC

11. A diatomic gas initally at 18ºC is compressed adiabatically to one eighth of its original volume. The temperature after compression will be

(a) 18ºC (b) 887ºC
(c) 327ºC (d) None of these

12. Absolute zero is obtained from

(a) P–V graph (b) $P-\frac{1}{V}$ graph
(c) P–T graph (d) V–T graph

13. 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

(a) 4.8×10^4 cal (b) 6×10^4 cal
(c) 2.4×10^4 cal (d) 1.2×10^4 cal

14. Three moles of an ideal gas kept at a constant temperature at 300 K are compressed from a volume of 4 litre to 1 litre. The work done in the process is

(a) – 10368 J (b) –110368 J
(c) 12000 J (d) 120368 J

15. The temperature at which speed of sound in air becomes double of its value at 27° C is

(a) 54ºC (b) 327ºC
(c) 927ºC (d) None of these

16. 1 gm of water at a pressure of 1.01×10^5 Pa is converted into steam without any change of temperature. The volume of 1 g of steam is 1671 cc and the latent heat of evaporation is 540 cal. The change in internal energy due to evaporation of 1 gm of water is

(a) $\approx$ 167 cal (b) $\approx$ 500 cal
(c) 540 cal (d) 581 cal

17. An ideal refrigerator has a freezer at a temperature of 13ºC. The coefficient of performance of the engine is 5. The temperature of the air (to which heat is rejected) is

(a) 320ºC (b) 39ºC
(c) 325 K (d) 325ºC

18. One mole of an ideal monoatomic gas is heated at a constant pressure of one atmosphere from 0ºC to 100ºC. Then the work done by the gas is

(a) 6.56 joule (b) 8.32×10^2 joule
(c) 12.48×10^2 joule (d) 20.8×10^2 joule

19. 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?

(a) $300\,(4)^{7/2}$ (b) $300\,(4)^{2/7}$
(c) $300\,(2)^{7/2}$ (d) $300\,(4)^{-2/7}$

20. A monatomic ideal gas expands at constant pressure, with heat Q supplied. The fraction of Q which goes as work done by the gas is

(a) 1 (b) $\frac{2}{3}$
(c) $\frac{3}{5}$ (d) $\frac{2}{5}$

21. 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

(a) 1000 K (b) 750 K
(c) 250 K (d) 125 K

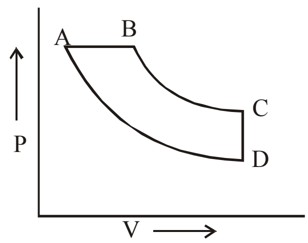
22. The source and sink temperatures of a Carnot engine are 400 K and 300 K, respectively. What is its efficiency?

(a) 100% (b) 75%
(c) 33.3% (d) 25%

23. The volume of a gas is reduced adiabatically to 1/4 of its volume at 27ºC. If $\gamma = 1.4$ the new temperature is

(a) $(300)\,2^{0.4}$ K (b) $(300)\,2^{1.4}$ K
(c) $300\,(4)^{0.4}$ K (d) $300\,(2)^{1.4}$ K

24. In pressure-volume diagram, the isochoric, isothermal, isobaric and iso-entropic parts respectively, are



(a) BA, AD, DC, CB (b) DC, CB, BA, AD
(c) AB, BC, CD, DA (d) CD, DA, AB, BC

25. Two cylinders fitted with pistons contain equal amount of an ideal diatomic gas at 300 K. The piston of A is free to move, while that of B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise in temperature of gas in B is
(a) 30 K (b) 18 K
(c) 50 K (d) 42 K

26. A Carnot engine works first between 200°C and 0°C and then between 0°C and –200°C. The ratio of its efficiency in the two cases is
(a) 1.0 (b) 0.577
(c) 0.34 (d) 0.68

27. A Carnot's engine works as a refrigerator between 250 K and 300 K. If it receives 750 calories of heat from the reservoir at the lower temperature, the amount of heat rejected at the higher temperature is
(a) 900 calories (b) 625 calories
(c) 750 calories (d) 1000 calories

28. A Carnot engine is working between 127°C and 27°C. The increase in efficiency will be maximum when the temperature of
(a) the source is increased by 50°C
(b) the sink is decreased by 50°C
(c) source is increased by 25°C and that of sink is decreased by 25°C
(d) both source and sink are decreased by 25°C each.

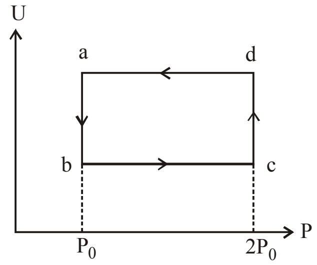
29. During an adiabatic process an object does 100J of work and its temperature decreases by 5K. During another process it does 25J of work and its temperature decreases by 5K. Its heat capacity for 2nd process is
(a) 20 J/K (b) 24 J/K
(c) 15 J/K (d) 100 J/K

30. The internal energy change in a system that has absorbed 2 kcals of heat and done 500 J of work is
(a) 6400 J (b) 5400 J
(c) 7900 J (d) 8900 J

31. In an adiabatic process, the pressure is increased by $\frac{2}{3}\%$. If $\gamma = \frac{3}{2}$, then the volume decreases by nearly
(a) $\frac{4}{9}\%$ (b) $\frac{2}{3}\%$
(c) 1% (d) $\frac{9}{4}\%$

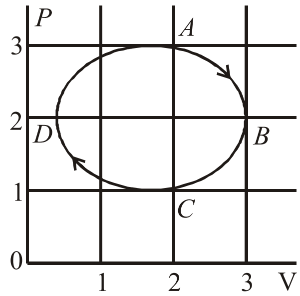
32. A closed gas cylinder is divided into two parts by a piston held tight. The pressure and volume of gas in two parts respectively are (P, 5V) and (10P, V). If now the piston is left free and the system undergoes isothermal process, then the volumes of the gas in two parts respectively are
(a) 2V,4V (b) 3V,3V
(c) 5V,V (d) $\frac{10}{11}V, \frac{20}{11}V$

33. Figure shows the variation of internal energy (U) with the pressure (P) of 2.0 mole gas in cyclic process abcda. The temperature of gas at c and d are 300 K and 500 K. Calculate the heat absorbed by the gas during the process.



(a) 400 R ln 2 (b) 200 R ln 2
(c) 100 R ln 2 (d) 300 R ln 2

34. The figure shows the P-V plot of an ideal gas taken through a cycle *ABCDA*. The part *ABC* is a semi-circle and *CDA* is half of an ellipse. Then,



(a) the process during the path A → B is isothermal
(b) heat flows out of the gas during the path B → C → D
(c) work done during the path A → B → C is zero
(d) positive work is done by the gas in the cycle *ABCDA*

35. A thermodynamic system goes from states (i) P_1, V to $2P_1$, V (ii) P, V_1 to P, $2V_1$. Then work done in the two cases is
(a) zero, zero (b) zero, PV_1
(c) PV_1, zero (d) PV_1, P_1V_1

36. For an isothermal expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal to
(a) $-\gamma^{1/2}\frac{\Delta V}{V}$ (b) $-\frac{\Delta V}{V}$
(c) $-\gamma\frac{\Delta V}{V}$ (d) $-\gamma^2\frac{\Delta V}{V}$

37. One mole of an ideal gas at an initial temperature of T K 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
(a) (T – 4) K (b) (T + 2.4) K
(c) (T – 2.4) K (d) (T + 4) K

38. If ΔU and ΔW represent the increase in internal energy and work done by the system respectively in a thermodynamical process, which of the following is true?

(a) $\Delta U = -\Delta W$, in an adiabatic process

(b) $\Delta U = \Delta W$, in an isothermal process

(c) $\Delta U = \Delta W$, in an adiabatic process

(d) $\Delta U = -\Delta W$, in an isothermal process

39. During an isothermal expansion, a confined ideal gas does –150 J of work against its surroundings. This implies that

(a) 150 J heat has been removed from the gas

(b) 300 J of heat has been added to the gas

(c) no heat is transferred because the process is isothermal

(d) 150 J of heat has been added to the gas

40. When 1 kg of ice at 0°C melts to water at 0°C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C, is

(a) 273 cal/K (b) 8 × 104 cal/K

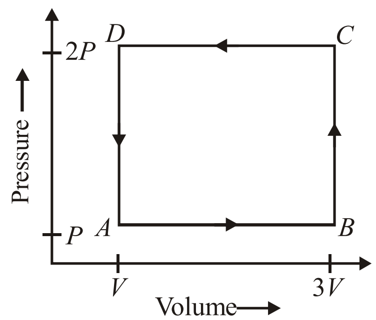
(c) 80 cal/K (d) 293 cal/K

41. A mass of diatomic gas (γ = 1.4) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in final state is

(a) 28 atm (b) 68.7 atm

(c) 256 atm (d) 8 atm

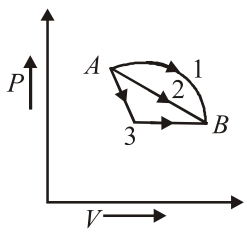
42. A thermodynamic system is taken through the cycle *ABCD* as shown in figure. Heat rejected by the gas during the cycle is



(a) 2PV (b) 4PV

(c) $\frac{1}{2}$ PV (d) PV

43. An ideal gas goes from state *A* to state *B* via three different processes as indicated in the *P-V* diagram :



If Q_1, Q_2, Q_3 indicate the heat a absorbed by the gas along the three processes and $\Delta U_1, \Delta U_2, \Delta U_3$ indicate the change in internal energy along the three processes respectively, then

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

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

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

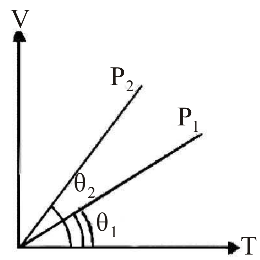
(d) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

44. Choose the correct relation between efficiency η of a Carnot engine and the heat absorbed (θ_1) and released by the working substance (θ_2).

(a) $\eta = 1 + \frac{\theta_2}{\theta_1}$ (b) $\eta = 1 + \frac{\theta_1}{\theta_2}$

(c) $\eta = 1 - \frac{\theta_1}{\theta_2}$ (d) $\eta = 1 - \frac{\theta_2}{\theta_1}$

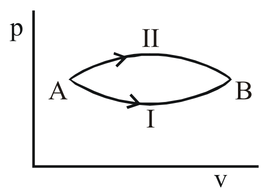
45. In the given (V – T) diagram, what is the relation between pressure P_1 and P_2 ?



(a) $P_2 > P_1$ (b) $P_2 < P_1$

(c) $P_2 = P_1$ (d) Cannot be predicted

46. A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then



(a) relation between ΔU_1 and ΔU_2 can not be determined

(b) $\Delta U_1 = \Delta U_2$

(c) $\Delta U_1 < \Delta U_2$

(d) $\Delta U_1 > \Delta U_2$

47. Which of the following statements about a thermodynamic process is wrong ?

(a) For an adiabatic process $\Delta E_{int} = -W$

(b) For a constant volume process $\Delta E_{int} = +Q$

(c) For a cyclic process $\Delta E_{int} = 0$

(d) For free expansion of a gas $\Delta E_{int} > 0$

48. In a Carnot engine efficiency is 40% at hot reservoir temperature T. For efficiency 50%, what will be the temperature of hot reservoir?

(a) T (b) $\frac{2}{3}$T

(c) $\frac{4}{5}$T (d) $\frac{6}{5}$T

Directions for Qs. (49 to 50) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following.

(a) Statement-1 is false, Statement-2 is true

(b) Statement-1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1

(c) Statement-1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1

(d) Statement-1 is true, Statement-2 is false

49. **Statement-1 :** At a given temperature the specific heat of a gas at constant volume is always greater than its specific heat at constant pressure.

Statement-2 : When a gas is heated at constant volume some extra heat is needed compared to that at constant pressure for doing work in expansion.

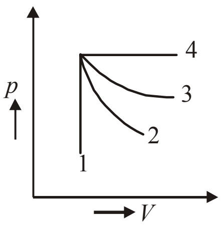
50. **Statement -1 :** If an ideal gas expands in vacuum in an insulated chamber, ΔQ, ΔU and ΔW all are zero.

Statement-2 : Temperature of the gas remains constant.

EXERCISE - 3
Exemplar & Past Years NEET/AIPMT Questions

Exemplar Questions

1. An ideal gas undergoes four different processes from the same initial state (figure). Four processes are adiabatic, isothermal, isobaric and isochoric. Out of 1, 2, 3 and 4 which one is adiabatic?

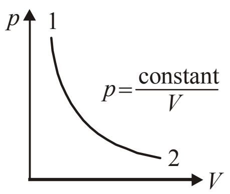


(a) 4 (b) 3
(c) 2 (d) 1

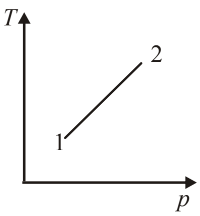
2. If an average person jogs, he produces 14.5×10^3 cal/min. This is removed by the evaporation of sweat. The amount of sweat evaporated per minute (assuming 1 kg requires 580×10^3 cal for evaporation) is

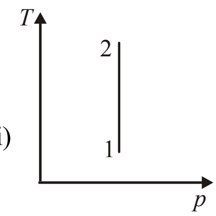
(a) 0.025 kg (b) 2.25 kg
(c) 0.05 kg (d) 0.20 kg

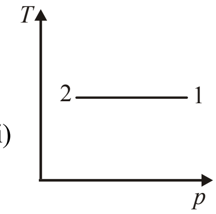
3. Consider *p-V* diagram for an ideal gas shown in figure.

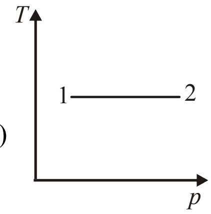


Out of the following diagrams, which figure represents the *T-p* diagram?

(i)


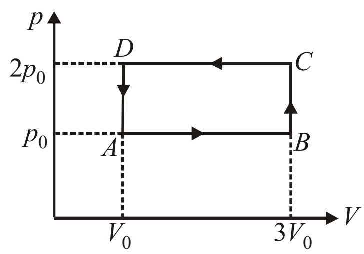
(ii)


(iii)


(iv)


(a) (iv) (b) (ii)
(c) (iii) (d) (i)

4. An ideal gas undergoes cyclic process *ABCDA* as shown in given *p-V* diagram. The amount of work done by the gas is



(a) $6p_0V_0$ (b) $-2p_0V_0$
(c) $+2p_0V_0$ (d) $+4p_0V_0$

5. Consider two containers *A* and *B* containing identical gases at the same pressure, volume and temperature. The gas in container *A* is compressed to half of its original volume isothermally while the gas in container *B* is compressed to half of its original value adiabatically. The ratio of final pressure of gas in *B* to that of gas in *A* is

(a) $2^{\gamma-1}$ (b) $\left(\frac{1}{2}\right)^{\gamma-1}$

(c) $\left(\frac{1}{1-\gamma}\right)^2$ (d) $\left(\frac{1}{\gamma-1}\right)^2$

6. Three copper blocks of masses M_1, M_2 and M_3 kg respectively are brought into thermal contact till they reach equilibrium. Before contact, they were at T_1, T_2, T_3 ($T_1 > T_2 > T_3$). Assuming there is no heat loss to the surroundings, the equilibrium temperature T is (s is specific heat of copper)

(a) $T = \frac{T_1 + T_2 + T_3}{3}$

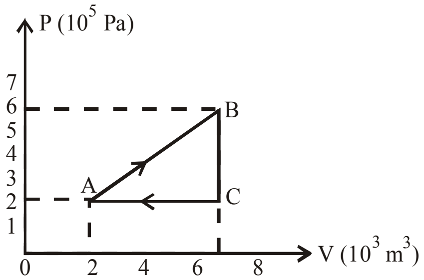
(b) $T = \frac{M_1T_1 + M_2T_2 + M_3T_3}{M_1 + M_2 + M_3}$

(c) $T = \frac{M_1T_1 + M_2T_2 + M_3T_3}{3(M_1 + M_2 + M_3)}$

(d) $T = \frac{M_1T_1s + M_2T_2s + M_3T_3s}{M_1 + M_2 + M_3}$

NEET/AIPMT (2013-2017) Questions

7. A gas is taken through the cycle $A \to B \to C \to A$, as shown in figure. What is the net work done by the gas ? **[2013]**

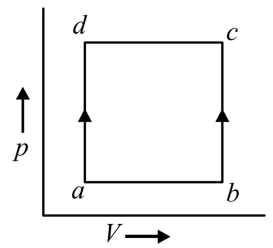


(a) 1000 J (b) zero
(c) – 2000 J (d) 2000 J

8. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is **[2013]**

(a) 2 (b) $\frac{5}{3}$
(c) $\frac{3}{2}$ (d) $\frac{4}{3}$

9. A system is taken from state a to state c by two paths adc and abc as shown in the figure. The internal energy at a is $U_a = 10$ J. Along the path adc the amount of heat absorbed $\delta Q_1 = 50$ J and the work done $\delta W_1 = 20$ J whereas along the path abc the heat absorbed $\delta Q_2 = 36$ J. The amount of work done along the path abc is **[NEET Kar. 2013]**



(a) 6 J (b) 10 J
(c) 12 J (d) 36 J

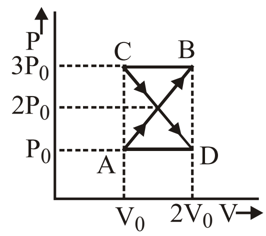
10. Which of the following relations does not give the equation of an adiabatic process, where terms have their usual meaning?

(a) $P^{\gamma}T^{1-\gamma}$ = constant **[NEET Kar. 2013]**
(b) $P^{1-\gamma}\, T^{\gamma}$ = constant
(c) PV^{γ} = constant
(d) $TV^{\gamma-1}$ = constant

11. Two Carnot engines A and B are operated in series. The engine A receives heat from the source at temperature T_1 and rejects the heat to the sink at temperature T. The second engine B receives the heat at temperature T and rejects to its sink at temperature T_2. For what value of T the efficiencies of the two engines are equal? **[NEET Kar. 2013]**

(a) $\frac{T_1 + T_2}{2}$ (b) $\frac{T_1 - T_2}{2}$
(c) T_1T_2 (d) $\sqrt{T_1T_2}$

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

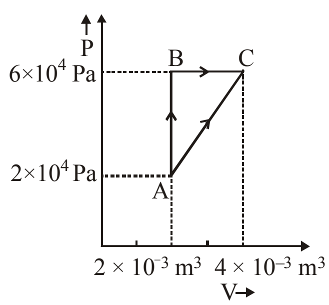


(a) P_0V_0
(b) $2P_0V_0$
(c) $\frac{P_0V_0}{2}$
(d) Zero

13. 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 $\gamma = \frac{5}{3}$) **[2014]**

(a) 64P (b) 32P
(c) $\frac{P}{64}$ (d) 16P

14. Figure below shows two paths that may be taken by a gas to go from a state A to a state C.



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 *[2015]*

(a) 500 J (b) 460 J
(c) 300 J (d) 380 J

15. A carnot engine having an efficiency of $\frac{1}{10}$ 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 :- *[2015, 2017]*

(a) 90 J (b) 99 J
(c) 100 J (d) 1 J

16. 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 RS]*

(a) 41°C (b) 11°C
(c) 21°C (d) 31°C

17. 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 RS]*

(a) Isobaric (b) Isochoric
(c) Isothermal (d) Adiabatic

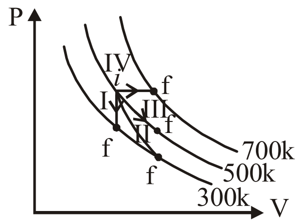
18. A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then : *[2016]*

(a) Compressing the gas isothermally will require more work to be done.
(b) Compressing the gas through adiabatic process will require more work to be done.
(c) Compressing the gas isothermally or adiabatically will require the same amount of work.
(d) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.

19. 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]*

(a) 2.365 W (b) 23.65 W
(c) 236.5 W (d) 2365 W

20. 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

(a) $P \to C, Q \to A, R \to D, S \to B$
(b) $P \to C, Q \to D, R \to B, S \to A$
(c) $P \to D, Q \to B, R \to A, S \to C$
(d) $P \to A, Q \to C, R \to D, S \to B$

Hints & Solutions

EXERCISE - 1

1. (c) 2. (c) 3. (b) 4. (a) 5. (a)
6. (b) 7. (b) 8. (b)

9. (a) Let P and V be the initial pressure and volume of ideal gas. After isothermal expansion, pressure is P/4. So volume is 4 V.
Let P_1 be the pressure after adiabatic compression. Then

$$P_1 V^\gamma = (P/4)(4V)^\gamma$$

$$P_1 = (P/4)(4)^{3/2} = 2P$$

10. (c) The temperature remains unchanged therefore
$U_f = U_i$.
Also, $\Delta Q = \Delta W$.
In the first step which is isochoric, $\Delta W = 0$.
In second step, pressure $= \frac{P}{n}$. Volume V is increased from V on nV.

$$\therefore \quad W = \frac{P}{n}(nV - V)$$

$$= PV\left(\frac{n-1}{n}\right)$$

$$= RT(1 - n^{-1})$$

11. (c) During melting temperature remains constant
12. (b) Flow rate $\propto$ gradient $\times r^2$.
When flow rate is constant, gradient $\propto r^{-2}$.
13. (d) Isochoric proceess $dV = 0$
$W = 0$ proceess 1
Isobaric : $W = P\,\Delta V = nR\Delta T$

Adiabatic $|W| = \frac{nR\Delta T}{\gamma - 1}$ $\quad 0 < \gamma - 1 < 1$

As workdone in case of adiabatic process is more so process 3 is adiabatic and process 2 is isobaric.

14. (a) Efficiency of carnot engine $= \eta = \frac{T_1 - T_2}{T_1}$

where T_1 = source temperature

T_2 = sink temperature.

15. (a) PV = constant represents isothermal process.
16. (c) 17. (c) 18. (a)
19. (b) $PV = RT$;

$$P = \frac{RT}{V} = \frac{RT^2}{a}$$

$$V = \frac{a}{T}$$

$$\therefore \; dV = -\frac{a}{T^2}dT$$

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

$$= \int \frac{RT^2}{a}\left(-\frac{a}{T^2}dT\right)$$

$$W = -R\,\Delta T$$

20. (b) $\Delta Q = \Delta U + \Delta W$
$\Rightarrow \Delta U = \Delta Q - \Delta W = Q - W$ (using proper sign)
21. (b) From FLOT $\Delta Q = \Delta U + \Delta W$
$\because$ Heat supplied to the system so $\Delta Q \to$ Positive and work is done on the system so $\Delta W \to$ Negative
Hence $+\Delta Q = \Delta U - \Delta W$
22. (a) In adiabatic process
$\Delta Q = 0$
$\therefore \; \Delta W = -\Delta U$
23. (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.
24. (a) In an isochoric process volume remains constant whereas pressure remains constant in isobaric process.
25. (a) $W = \frac{nRdT}{\gamma - 1}$ γ is minimum for a polyatomic gas
Hence, W is greatest for polyatomic gas

EXERCISE - 2

1. (a) We know that $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \therefore \; T_2 = \frac{P_2 V_2 T_1}{P_1 V_1}$
Here $P_1 = 30$ atm., $P_2 = 1$ atm, $V_1 = V$ (say), $V_2 = 15\,V$, $T_1 = 27^\circ C = 27 + 273 = 300^\circ K$ and $T_2 = ?$
Substituting these values, we get $T_2 = 150^\circ K$
$\therefore \; T_2 = 150^\circ K = 150 - 273 = -123^\circ C$.

2. (c) $W = \frac{(1\times 10^5 + 6\times 10^5)\,(5-1)}{2}$

$$= \frac{6\times 10^5 \times 4}{2} = 12\times 10^5 \text{ joule}$$

3. (a) $\frac{T_2}{T_1 - T_2} = \frac{Q_2}{W}$

$$\frac{273}{300-273}=\frac{50,000}{W}$$

$$W=\frac{27\times 50,000}{273}\text{cal/min}$$

$$P=\frac{W}{t}=\frac{4.2\times 27\times 50,000}{60\times 273}\text{Joule/sec}$$
$$=346\text{ watt}=0.346\text{ kW}$$

4. (d) $dU=dQ-dW=(8\times10^5-6.5\times10^5)\ =1.5\times10^5$ J

$dW=dQ-dU==10^5-1.5\times10^5\ =-0.5\times10^5\ J$

– ve sign indicates that work done on the gas is 0.5×10^5 J.

5. (c) $dU=nC_V\,dT$ or $80=5\times C_V(120-100)$

$C_V=4.0$ joule/K

6. (b) $P_0V^{4/3}=P_1\left(\frac{V}{8}\right)^{4/3}\Rightarrow P_1=P_0 8^{4/3}=16P_o$

7. (c) $\eta=1-\frac{T_2}{T_1}\Rightarrow\eta=1-\frac{250}{373}=\frac{123}{373}=\frac{100+23}{373}$

8. (d) $\frac{PV}{T}=\frac{P'(90/100)V}{T}$

or $\frac{P'}{P}=\frac{100}{90}=1+\frac{10}{90}$

or $\frac{P'-P}{P}=\frac{10}{90}=11.1\%$

9. (d) $PV^\gamma=P_1\left(\frac{V}{32}\right)^\gamma$

or $P_1=(32)^\gamma$, $P=(32)^{1.4}$, $P=128P$

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

11. (d) $T_1=18^\circ C=(273+18)=291\text{ K}$

and $V_2=V_1/8$

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

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

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

$$=668.5\text{ K}=395.5^\circ C$$

12. (c) $P\propto T$ if V is constant, where P is pressure of certain amount of gas and T is absolute zero temperature.

13. (d) We know that efficiency of carnot engine $=1-\frac{T_L}{T_H}$

Also, Efficiency of Heat engine $=\frac{\text{Work output}}{\text{Heat input}}$

$$\therefore\ 1-\frac{T_L}{T_H}=\frac{W}{Q_S}$$

$$\Rightarrow W=Q_S\left(1-\frac{T_L}{T_H}\right)$$

$$=6\times10^4\left(1-\frac{127+273}{227+273}\right)$$

$$=1.2\times10^4\text{ cal}$$

14. (a) Work done in an isothermal process is given by

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

Here, $n=3$, $R=8.31\text{ J mol}^{-1}\text{ degree}^{-1}$

$T=300$ K, $V_1=4$ litre, $V_2=1$ litre.

Hence, $W=2.3026\times3\times8.31\times300\times\log_{10}\frac{1}{4}$

$=17221.15(-2\log_{10}2)$

$=-17221.15\times2\times0.3010=-10368$ J.

15. (c) The speed of sound in air, $v\propto\sqrt{T}$

$$\frac{v_1}{v_2}=\sqrt{\frac{T_1}{T_2}}$$

$$\Rightarrow\frac{v_1}{2v_1}=\sqrt{\frac{(27+273)}{T_2}}$$

$$\frac{1}{2}=\sqrt{\frac{300}{T_2}}$$

$T_2=1200\text{ K}=(1200-273)^\circ C=927^\circ C$

16. (b) $dW=P\Delta V=1.01\times10^5[1671-1]\times10^{-6}$ Joule

$$=\frac{1.01\times167}{4.2}\text{cal.}$$

$=40$ cal. nearly

$\Delta Q=mL=1\times540$,

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

or $\Delta U=540-40=500$ cal.

17. (b) $T_2=273-13=260$,

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

$$5=\frac{260}{T_1-260}$$

or $T_1-260=52$

$T_1=312\text{ K}$,

$T_2=312-273=39^\circ C$

18. (b) $dQ = n\,C_p dT = 1 \times \frac{5}{2} R \times 100$

$= 2077.5\,J = 20.8 \times 10^2\,J$

$dU = n\,C_V dT$

$= 1 \times \frac{3}{2} R \times 100$

$= 1246.5\,J$

$\therefore\ dU = dQ - dU$

$= 8.31 \times 10^2\,J$

19. (d) Under adiabatic change

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

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

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

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

20. (d) $Q = nC_p\Delta T$ and $W = P\Delta V = nR\Delta T.$

For monatomic gas, $C_p = \frac{5R}{2}$. $\Rightarrow \frac{W}{Q} = \frac{2}{5}$

21. (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 $T_2 = \frac{Q_2 \times T_1}{Q_1} = \frac{150 \times 500}{300} = 250K$

22. (d) Efficiency, $\eta = 1 - \frac{T_2}{T_1}$

T_1 (source temp.) = 400 K

T_2 (sink temp.) = 300 K

$\therefore \eta = 1 - \frac{300}{400} = \frac{1}{4} = 25\%$

23. (c) $(300)\ V^{(1.4-1)} = T_2 . \left(\frac{V}{4}\right)^{(1.4-1)}$

$T_2 = (300)(4)^{0.4}$

24. (d) From C to D, V is constant. So process is isochoric. From D to A, the curve represents constant temperature. So the process is isothermal.
From A to B, pressure is constant . So, the process is isobaric.
BC represents constant entropy.

25. (d) In cylinder A, heat is supplied at constant pressure while in cylinder B heat is supplied at constant volume.

$(\Delta Q)_A = nC_P(\Delta T)_A$

and $(\Delta Q)_B = nC_V(\Delta T)_B$

Given : $(\Delta Q)_A = (\Delta Q)_B$

$\therefore\ (\Delta T)_B = \frac{C_P}{C_V}(\Delta T)_A$

$= 1.4 \times 30$

$= 42K$

[$\because$ for diatomic gas $\frac{C_P}{C_V} = 1.4$]

26. (b) $\eta = 1 - \frac{T_2}{T_1}$

$= 1 - \frac{273 + 0}{273 + 200}$

$= \frac{200}{473}$

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

$= 1 - \frac{(273 - 200)}{273 + 0}$

$= \frac{200}{473}$

$\frac{\eta}{\eta'} = \frac{200}{473} \times \frac{273}{200}$

$= 0.577$

27. (a) $\frac{750}{W} = \frac{250}{300 - 250}$

Heat rejected = 750 + 150 = 900 cal.

28. (b) $\frac{T_1 - T_2}{T_1}$ is maximum in case (b).

29. (c) For adiabatic process, dU = – 100 J
which remains same for other processes also.
Let C be the heat capacity of 2nd process then

$-(C)\,5 = dU + dW$

$= -100 + 25 = -75$

$\therefore\ C = 15\,J/K$

30. (c) According to first law of thermodynamics

$Q = \Delta U + W$

$\Delta U = Q - W$

$= 2 \times 4.2 \times 1000 - 500$

$= 8400 - 500 = 7900\,J$

31. (a) $PV^{3/2} = K$

$\log P + \frac{3}{2}\log V = \log K$

$\frac{\Delta P}{P} + \frac{3}{2}\frac{\Delta V}{V} = 0$

$\frac{\Delta V}{V} = -\frac{2}{3}\frac{\Delta P}{P}$

or $\frac{\Delta V}{V} = \left(-\frac{2}{3}\right)\left(\frac{2}{3}\right)$

$= -\frac{4}{9}$

32. (a) The volume on both sides will be so adjusted that the original pressure × volume is kept constant as the piston moves slowly (isothermal change)
P5V = P'V' .... (1)
10PV = P'V" .... (2)
From (1) and (2), V" = 2V'
and from V' + V" = 6V
V' = 2V, V" = 4V

33. (a) Change in internal energy for cyclic process $(\Delta U) = 0$.
For process a → b, (P-constant)

$W_{a\to b} = P\Delta V$

$= nR\Delta T$

$= -400R$

For process b → c, (T-constant)

$W_{b\to c} = -2R\ (300)\ \ln 2$

For process c → d, (P-constant)

$W_{c\to d} = +400R$

For process d → a, (T-constant)

$W_{d\to a} = +2R\ (500)\ \ln 2$

Net work $(\Delta W) = W_{a\to b} + W_{b\to c} + W_{c\to d} + W_{d\to a}$

$\Delta W = 400R\ \ln 2$

∴ $dQ = dU + dW$, first law of thermodynamics

∴ $dQ = 400\ R\ \ln 2$.

34. (b,d) (a) Process is not isothermal.
(b) Volume decreases and temperature decreases ΔU = negative,
So, ΔQ = negative
(c) Work done in process A → B → C is positve
(d) Cycle is clockwise, so work done by the gas is positive

35. (b) (i) Case → Volume = constant ⇒ $\int PdV = 0$
(ii) Case → P = constant

$$\Rightarrow \int_{V_1}^{2V_1} PdV = P\int_{V_1}^{2V_1} dV = PV_1$$

36. (b) Differentiate PV = constant w.r.t V

$\Rightarrow P\Delta V + V\Delta P = 0$

$\Rightarrow \frac{\Delta P}{P} = -\frac{\Delta V}{V}$

37. (a) $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{nRT_1 - nRT_2}{\gamma - 1} = \frac{nR(T_1 - T_2)}{\gamma - 1}$

$n = 1, T_1 = T \Rightarrow \frac{R(T - T_2)}{5/3 - 1} = 6R \Rightarrow T_f = (T - 4)K$

38. (a) By first law of thermodynamics,
$\Delta Q = \Delta U + \Delta W$
In adiabatic process, $\Delta Q = 0$
∴ $\Delta U = -\Delta W$
In isothermal process, $\Delta U = 0$
∴ $\Delta Q = \Delta W$

39. (a, d) If a process is expansion then work done is positive so answer will be (a).
But in question work done by gas is given –150J so that according to it answer will be (d).

40. (d) Change in entropy is given by

$dS = \frac{dQ}{T}$ or $\Delta S = \frac{\Delta Q}{T} = \frac{mL_f}{273}$

$\Delta S = \frac{1000 \times 80}{273} = 293\ \text{cal/K}$.

41. (c) $T_1 = 273 + 27 = 300K$
$T_2 = 273 + 927 = 1200K$
For adiabatic process,
$P^{1-\gamma}\ T^{\gamma}$ = constant
$\Rightarrow P_1^{1-\gamma}\ T_1^{\gamma} = P_2^{1-\gamma}\ T_2^{\gamma}$

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

$\Rightarrow \left(\frac{P_1}{T_2}\right)^{1-\gamma} = \left(\frac{T_2}{T_1}\right)^{\gamma}$

$\left(\frac{P_1}{P_2}\right)^{1-1.4} = \left(\frac{1200}{300}\right)^{1.4}$

$\left(\frac{P_1}{P_2}\right)^{-0.4} = (4)^{1.4}$

$\left(\frac{P_2}{P_1}\right)^{0.4} = 4^{1.4}$

$P_2 = P_1\ 4^{\left(\frac{1.4}{0.4}\right)} = P_1\ 4^{\left(\frac{7}{2}\right)}$

$= P_1\ (2^7) = 2 \times 128 = 256$ atm

42. (a) ∵ Internal energy is the state function.
∴ In cyclie process; $\Delta U = 0$
According to 1st law of thermodynamics

$\boxed{\Delta Q = \Delta U + W}$

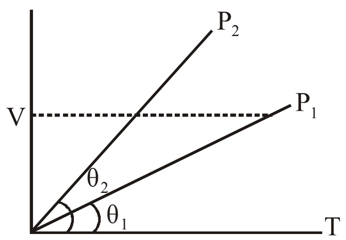
So heat absorbed
$\Delta Q = W$ = Area under the curve
$= -\ (2V)(P) = -\ 2PV$
So heat rejected = 2PV

43. (a) Initial and final condition is same for all process
$\Delta U_1 = \Delta U_2 = \Delta U_3$
from first law of thermodynamics
$\Delta Q = \Delta U + \Delta W$
Work done
$\Delta W_1 > \Delta W_2 > \Delta W_3$ (Area of P.V. graph)
So $\Delta Q_1 > \Delta Q_2 > \Delta Q_3$

44. (d) Efficiency $\eta = \frac{W}{\theta_1}$ and $W = \theta_1 - \theta_2$

$\therefore \quad \eta = \frac{\theta_1 - \theta_2}{\theta_1} = 1 - \frac{\theta_2}{\theta_1}$

45. (b) $P_1 > P_2$



As V = constant $\Rightarrow P \propto T$
Hence from V–T graph $P_1 > P_2$

46. (b) Change in internal energy do not depend upon the path followed by the process. It only depends on initial and final states i.e.,
$$\Delta U_1 = \Delta U_2$$

47. (a) For adiabatic process Q = 0.
By first law of thermodynamics,
$Q = \Delta E + W$
$\Rightarrow \Delta E_{int} = -W.$

48. (d) The efficiency of carnot's heat engine

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

where T_2 is temperature of sink, and T_1 is temperature of hot reservoir or source.

When efficiency is 40% i.e. $\eta = 40/100 = 1 - \frac{T_2}{T_1}$

or $\frac{2}{5} = 1 - \frac{T_2}{T} [T_1 = T(\text{given})]$

$\therefore \quad T_2 = \frac{3}{5}T$

Now, when efficiency is 50%

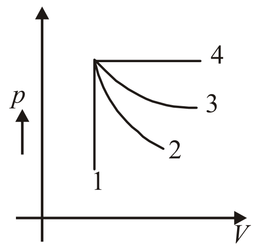
$$\eta = \frac{50}{100} = 1 - \frac{\frac{3}{5}T}{T^1} \therefore T^1 = \frac{6}{5}T$$

49. (a) 50. (c)

EXERCISE - 3

Exemplar Questions

1. (c) For the straight line in the graph denoted by 4, that shows pressure is constant, so curve 4 represents an isobaric process.



For the straight line in graph denoted by 1, that shows volume is constant, so curve 1 represents isochoric process. Out of curves 3 and 2, curve 2 is steeper. Hence, curve 2 is adiabatic and curve 3 is isothermal.

2. (a) As we know that amount of sweat evaporated/minute

$$= \frac{\text{Sweat produced/ minute}}{\text{Number of calories required for evaporation/kg}}$$

$$= \frac{\text{Amount of heat produced per minute in jogging}}{\text{Latent heat (in cal/kg)}}$$

580×10^3 calories are needed to convert 1 kg H_2O into stream.
1 cal. will produce sweat = 1 kg/ 580×10^3
14.5×10^3 cal will produce (sweat)

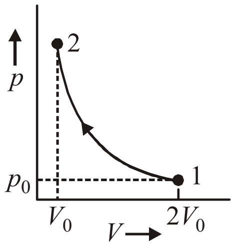
$$= \frac{14.5 \times 10^3}{580 \times 10^3} \text{kg} = \frac{145}{580} \text{kg/m}$$

= 0.025 kg.

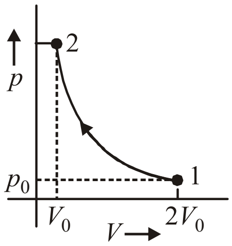
3. (c) According to given P–V diagram that
pV = constant
So we can say that the gas is going through an isothermal process.
If pressure (P) increase at constant temperature volume V decreases, the graph (iii) shows that pressure (P) is smaller at point 2 and larger at point 1 point so the gas expands and pressure decreases. Hence verifies option (c).

4. (b) According to the given p-V diagram.
Work done in the process $ABCD$
$= (AB) \times BC = (3V_0 - V_0) \times (2p_0 - p_0)$
$= 2V_0 \times p_0 = 2p_0V_0$
Here the direction of arrow is anti-clockwise, so work done is negative.
Hence, work done by the gas $= -2p_0V_0$
That shows external work done on the system.

5. (a) Let us consider the p-V diagram for container A (isothermal) and for container B (adiabatic).



Container *A* (Isothermal)



Container *B* (Adiabatic)

In both process compression of the gas.

For isothermal process (gas *A*) during $1 \to 2$

$p_1V_1 = p_2V_2 \qquad (\because V_1 = 2V_0, V_2 = V_0)$

$p_0(2V_0) = p_2(V_0)$

$p_2 = 2p_0$

For adiabatic process, (gas *B*) during $(1 \to 2)$

$p_1V_1^\gamma = p_2V_2^\gamma \qquad (\because V_1 = 2V_0, V_2 = V_0)$

$p_0(2V_0)^\gamma = p_2(V_0)^\gamma$

$$p_2 = \left(\frac{2V_0}{V_0}\right)^\gamma p_0 = (2)^\gamma p_0$$

So, ratio of final pressure

$$= \left(\frac{(p_2)_B}{(p_1)_A}\right) = \frac{(2)^\gamma p_0}{2p_0} = 2^{\gamma-1}$$

where, γ is ratio of specific heat capacities for the gas.

Hence, verifies the option (a).

6. (b) Consider the equilibrium temperature of the system is *T*.

Let us consider, $T_1, T_2 < T < T_3$.

As given that, there is no net loss to the surroundings.

Heat lost by M_3 = Heat gained by M_1 + Heat gained by M_2

$M_3s(T_3 - T) = M_1s(T - T_1) + M_2s(T - T_2)$

$M_3sT_3 - M_3sT = M_1sT - M_1sT_1 + M_2sT - M_2sT_2$

(where, *s* is specified heat of the copper material)

$T[M_1 + M_2 + M_3] = M_3T_3 + M_1T_1 + M_2T_2$

$$T = \frac{M_1T_1 + M_2T_2 + M_3T_3}{M_1 + M_2 + M_3}$$

NEET/AIPMT (2013-2017) Questions

7. (a) W_{net} = Area of triangle ABC

$$= \frac{1}{2} AC \times BC$$

$$= \frac{1}{2} \times 5 \times 10^{-3} \times 4 \times 10^5 = 1000 \text{ J}$$

8. (c) According to question $P \propto T^3$

But as we know for an adiabatic process the pressure $P \propto T^{\frac{\gamma}{\gamma-1}}$.

So, $\frac{\gamma}{\gamma-1} = 3 \Rightarrow \gamma = \frac{3}{2}$ or, $\frac{C_p}{C_v} = \frac{3}{2}$

9. (a) From first law of thermodynamics

$Q_{adc} = \Delta U_{adc} + W_{adc}$

$50 \text{ J} = \Delta U_{adc} + 20 \text{ J}$

$\Delta U_{adc} = 30 \text{ J}$

Again, $Q_{abc} = \Delta U_{abc} + W_{abc}$

$W_{abc} = Q_{abc} - \Delta U_{abc}$

$= Q_{abc} - \Delta U_{adc}$

$= 36 \text{ J} - 30 \text{ J}$

$= 6 \text{ J}$

10. (a) Adiabatic equations of state are

PV^γ = constant

$TV^{\gamma-1}$ = constant

$P^{1-\gamma}T^\gamma$ = constant.

11. (d) Efficiency of engine *A*, $\eta_1 = 1 - \frac{T}{T_1}$,

Efficiency of engine *B*, $\eta_2 = 1 - \frac{T_2}{T}$

Here, $\eta_1 = \eta_2$

$\therefore \frac{T}{T_1} = \frac{T_2}{T} \Rightarrow T = \sqrt{T_1T_2}$

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

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

For adiabatic process

$P_2V_2^\gamma = P_3V_3^\gamma$

$\Rightarrow \left(\frac{P}{2}\right)(2v)^\gamma = P_3 16v)^\gamma$

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

14. (b) In cyclic process ABCA

$Q_{cycle} = W_{cycle}$

$Q_{AB} + Q_{BC} + Q_{CA} = \text{ar. of } \Delta ABC$

$+400 + 100 + Q_{C\to A} = \frac{1}{2}(2\times10^{-3})(4\times10^{4})$

$\Rightarrow Q_{C\to A} = -460\text{ J}$

$\Rightarrow Q_{A\to C} = +460\text{ J}$

15. (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

$Q_2 = \beta w$

$Q_2 = 9 \times 10 = 90\text{ J}$

16. (d) Coefficient of performance,

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

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

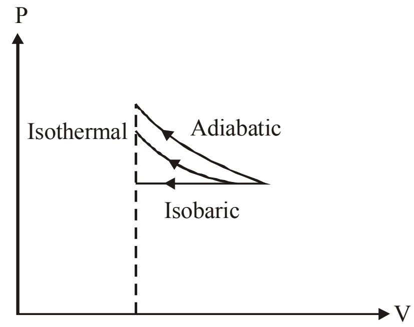
$5T_1 - (5\times253) = 253$

$5T_1 = 253 + (5\times253) = 1518$

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

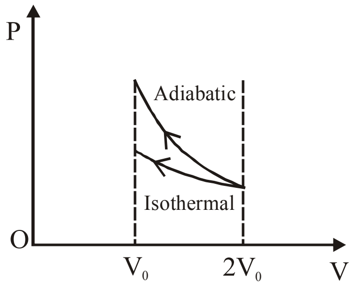
or, $T_1 = 303.6 - 273 = 30.6 \cong 31°C$

17. (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



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

W(adiabatic) > W(isothermal)



19. (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: $T_2 = 4°C = 4 + 273 = 277\text{ k}$

$T_1 = 30°C = 30 + 273 = 303\text{ k}$

$\therefore \beta = \frac{600\times4.2}{W} = \frac{277}{303-277}$

$\Rightarrow W = 236.5\text{ joule}$

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

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

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