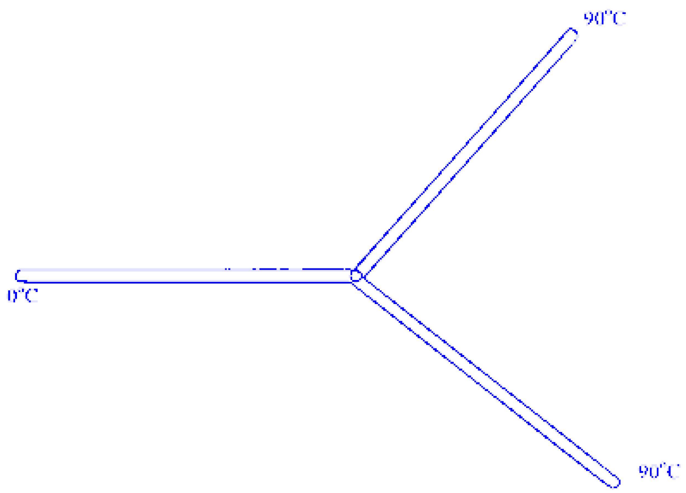
Heat and Thermodynamics

Question1

Three metal rods of the same material and identical in all respects are joined as shown in the figure. The temperatures at the ends of these rods are maintained as indicated. Assuming no heat energy loss occurs through the curved surfaces of the rods, the temperature at the junction x is



KCET 2025

Options:

A. 60°C

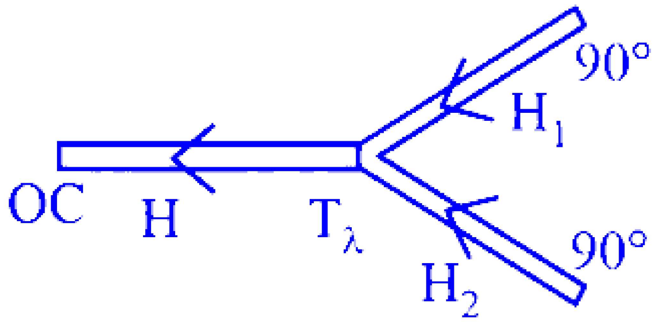
B. 30°C

C. 20°C

D. 45°C

Answer: A

Solution:



To determine the temperature at the junction x of three identical metal rods, follow this analysis:

Assuming No Heat Loss: The rods are made of the same material and are identical, ensuring consistent heat flow throughout.

Thermal Resistance: Let the thermal resistance of each rod be R. The temperature at the junction is T_x.

Heat Flow Equilibrium: Since the system reaches a steady state, the heat flowing into the junction from each side should equal the heat flowing out:

$H = H_1 + H_2$

Where:

H is the heat flowing into the junction from both ends.

H_1 and H_2 are the heat flows from the sides of the junction.

Application: Set up the heat balance equation:

$\frac{T_x-0}{R} = \frac{90-T_x}{R} + \frac{90-T_x}{R}$

Simplifying: Substitute and solve:

$T_x = \frac{180}{3} = 60°\text{C}$

Therefore, the temperature at the junction x is 60°C. This calculation assumes perfect thermal conduction and no heat loss outside the system.

Question2

A gas is taken from state A to state B along two different paths 1 and 2. The heat absorbed and work done by the system along these two paths are Q_1 and Q_2 and W_1 and W_2 respectively. Then

KCET 2025

Options:

A. $W_1 = W_2$

B. $Q_1 - W_1 = Q_2 - W_2$

C. $Q_1 + W_1 = Q_2 + W_2$

D. $Q_1 = Q_2$

Answer: B

Solution:

According to the first law of thermodynamics, the change in internal energy (ΔU) of a system can be expressed as:

$\Delta U = Q - W$

Where Q is the heat absorbed by the system and W is the work done by the system.

For paths 1 and 2 from state A to state B, the change in internal energy is the same, regardless of the path taken:

$\Delta U_1 = \Delta U_2$

Therefore, the heat absorbed and work done along the different paths follows the relationship:

$Q_1 - W_1 = Q_2 - W_2$

This equation signifies that the net change in energy (considering both heat and work) is equal for both paths due to the same change in internal energy from state A to state B.

Question3

At 27°C temperature, the mean kinetic energy of the atoms of an ideal gas is E_1. If the temperature is increased to 327°C, then the mean kinetic energy of the atoms will be

KCET 2025

Options:

A. $\frac{E_1}{\sqrt{2}}$

B. $\sqrt{2}E_1$

C. $2E_1$

D. $\frac{E_1}{2}$

Answer: C

Solution:

The mean kinetic energy of the atoms in an ideal gas is directly proportional to the temperature measured in Kelvin. At an initial temperature of 27°C, the mean kinetic energy is E_1. When the temperature is increased to 327°C, we can determine the new mean kinetic energy E_2 using the relationship:

$\frac{E_1}{E_2} = \frac{T_1}{T_2}$

To find E_2, we can rearrange this equation:

$E_2 = E_1 \frac{T_2}{T_1}$

Converting the given temperatures from Celsius to Kelvin:

Initial temperature, $T_1 = 27^\circ C + 273 = 300K$

Final temperature, $T_2 = 327^\circ C + 273 = 600K$

Substituting these values into the equation:

$E_2 = E_1 \left(\frac{600}{300}\right) = E_1 \times 2 = 2E_1$

Therefore, when the temperature increases to 327°C, the mean kinetic energy of the atoms will be $2E_1$.

Question4

The ratio of molar specific heats of oxygen is

KCET 2024

Options:

A. 1.4

B. 1.67

C. 1.33

D. 1.28

Answer: A

Solution:

The ratio of molar specific heats (C_p and C_V) is

$\gamma = 1 + \frac{2}{f}$

For O_2,

$$f = 5$$

$$\therefore \quad \gamma = 1 + \frac{2}{5} = 1 + 0.4 = 1.4$$

Question5

A solid cube of mass m at a temperature θ_0 is heated at a constant rate. It becomes liquid at temperature θ_1 and vapour at temperature θ_2. Let s_1 and s_2 be specific heats in its solid and liquid states respectively. If L_f and L_v are latent heats of fusion and vaporisation respectively, then the minimum heat energy supplied to the cube until it vaporises is

KCET 2024

Options:

A. $m s_1 (\theta_1 - \theta_0) + m s_2 (\theta_2 - \theta_1)$

B. $m L_f + m s_2 (\theta_2 - \theta_1) + m L_v$

C. $m s_1 (\theta_1 - \theta_0) + m L_f + m s_2 (\theta_2 - \theta_1) + m L_v$

D. $m s_1 (\theta_1 - \theta_0) + m L_f + m s_2 (\theta_2 - \theta_0) + m L_v$

Answer: C

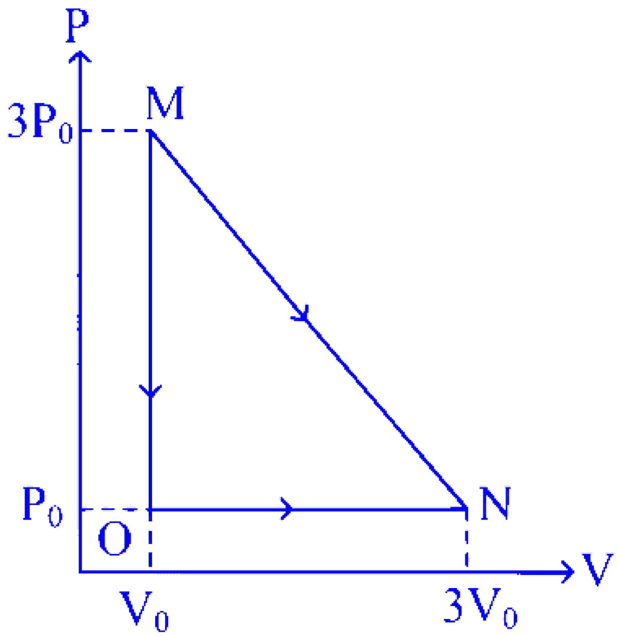
Solution:

Minimum heat energy supplied to the cube until it vaporises, is given as $Q =$ heat given to liquify at $\theta_1 + m \times$ latent heat of fusion + heat given to vaporise at $\theta_2 + m \times$ latent Heat of vaporisation

$= m s_1 (\theta_1 - \theta_0) + m L_f + m s_2 (\theta_2 - \theta_1) + m L_2$

Question6

One mole of an ideal monoatomic gas is taken round the cyclic process MNOM. The work done by the gas is



KCET 2024

Options:

A. $4.5p_0V_0$

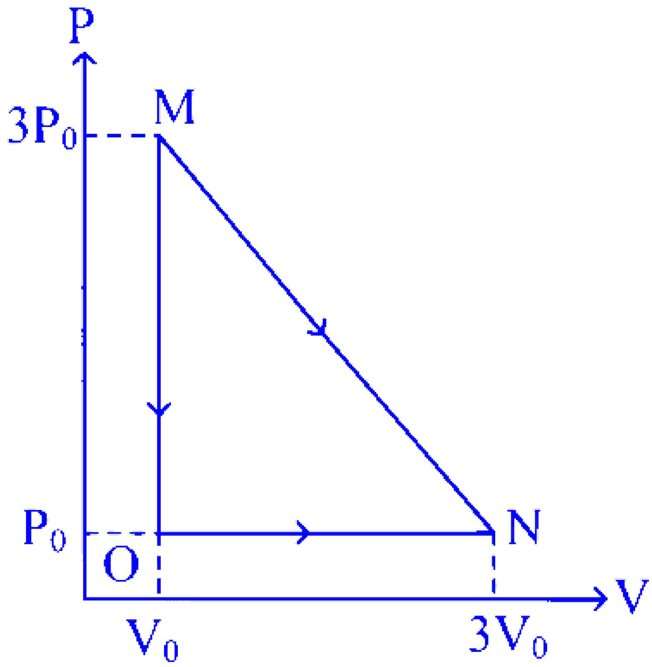
B. $4p_0V_0$

C. $9p_0V_0$

D. $2p_0V_0$

Answer: D

Solution:



$$W = \text{Area enclosed in cyclic process}$$
$$= \frac{1}{2} \times ON \times OM$$
$$= \frac{1}{2} \times (3V_0 - V_0) \times (3p_0 - p_0)$$
$$= V_0 \times 2p_0 = 2p_0V_0$$

Question7

100 g of ice at 0°C is mixed with 100 g of water at 100°C. The final temperature of the mixture is

[Take, $L_f = 3.36 \times 10^5 \mathrm{~J~kg}^{-1}$ and $S_w = 4.2 \times 10^3 \mathrm{~J~kg}^{-1} \mathrm{~K}^{-1}$]

KCET 2023

Options:

A. 40°C

B. 10°C

C. 50°C

D. 1°C

Answer: B

Solution:

Let the final temperature of mixture be T.

Heat absorbed by ice = heat lost by water

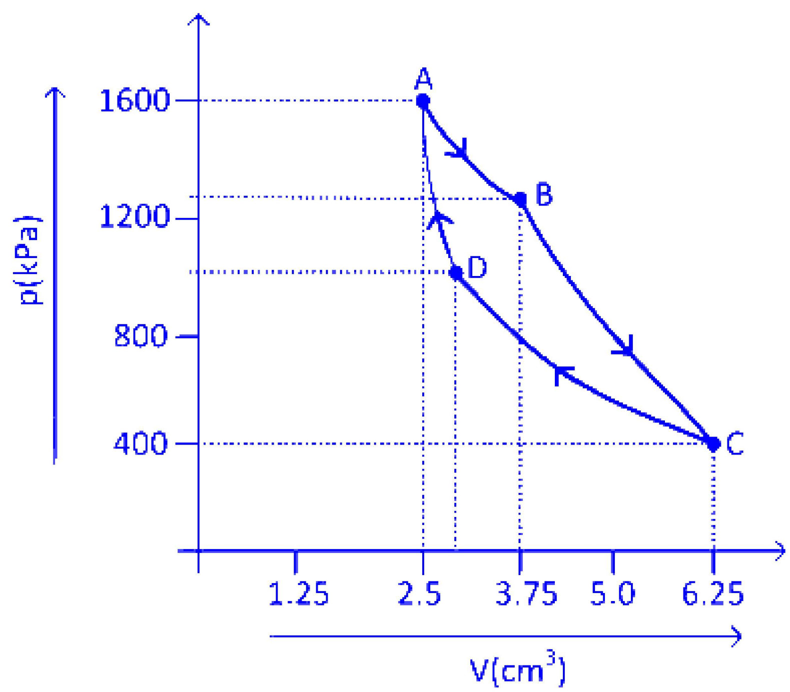
$\therefore mL + mc(T - 0) = mc(100 - T)$

Substituting values,

$$\begin{aligned} \therefore \quad (100 \times 80) + (100 \times 1)T &= 100 \times 1(100 - T) \\ \therefore \quad 8000 + 100T &= 10000 - 100T \\ \therefore \quad 200T &= 2000 \\ T &= 10^\circ\mathrm{C} \end{aligned}$$

Question8

The p-V diagram of a Carnot's engine is shown in the graph below. The engine uses 1 mole of an ideal gas as working substance. From the graph, the area enclosed by the p-V diagram is [The heat supplied to the gas is 8000 J]



KCET 2023

Options:

A. 1200 J

B. 2000 J

C. 3000 J

D. 1000 J

Answer: A

Solution:

[Hint Area enclosed by p-V diagram is equal to work done] Total work done by gas in one carnot cycle is given by.

$W=\mu R T_1 \ln \frac{V_2}{V_1}-\mu R T_2 \ln \frac{V_3}{V_4}$

Question9

The speed of sound in an ideal gas at a given temperature T is v. The rms speed of gas molecules at that temperature is v_{rms}. The ratio of the velocities v and v_{rms} for helium and oxygen gases are X and X' respectively. Then, $\frac{X}{X'}$ is equal to

KCET 2023

Options:

A. $\frac{21}{\sqrt{5}}$

B. $\frac{5}{\sqrt{21}}$

C. $\sqrt{\frac{5}{21}}$

D. $\frac{21}{5}$

Answer: B

Solution:

The speed of sound at a given temperature is given by

$$v_{\text{sound}} = \sqrt{\frac{rRT}{M}} \Rightarrow v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

For oxygen molecules; $\frac{v_O}{v_{\text{rms}}} = \frac{\sqrt{\frac{r_O RT}{M}}}{\sqrt{\frac{3RT}{M}}} = \sqrt{\frac{r_O}{3}}$

For helium molecules; $\frac{v_{\text{He}}}{v_{\text{rms}}} = \frac{\sqrt{r_{\text{He}}\frac{RT}{M}}}{\sqrt{\frac{3RT}{M}}} = \sqrt{\frac{r_{\text{He}}}{3}} \left(r_{\text{He}} = \frac{5}{3}, r_O = \frac{7}{5}\right)$

$$\frac{x'}{x} = \frac{\sqrt{\frac{5}{9}}}{\sqrt{\frac{7}{15}}} = \sqrt{\frac{25}{21}} = \frac{5}{\sqrt{21}}$$

Question10

Pressure of ideal gas at constant volume is proportional to ....

KCET 2023

Options:

A. force between the molecules

B. average potential energy of the molecules

C. total energy of the gas

D. average kinetic energy of the molecules

Answer: D

Solution:

Gay Lussac's law states that the pressure of a fixed mass of a gas at constant volume is directly proportional to the temperature.

i.e. $p \propto T$

or $p \propto \frac{1}{2} K_B T$

Since kinetic energy of the molecules is directly proportional to the temperature.

Question11

"Heat cannot be flow itself from a body at lower temperature to a body at higher temperature". This statement corresponds to

KCET 2022

Options:

A. conservation of momentum

B. conservation of mass

C. first law of thermodynamics

D. second law of thermodynamics

Answer: D

Solution:

According to second law of thermodynamics, heat cannot be itself flow from a body at lower temperature to a body at higher temperature without doing external work.

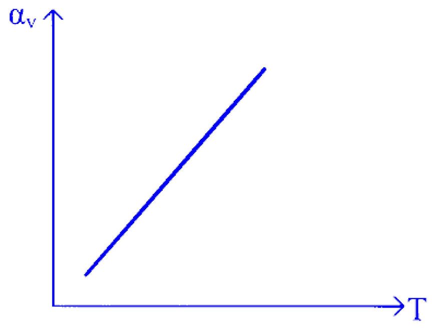
Question12

Which of the following curves represent the variation of coefficient of volume expansion of an ideal gas at constant pressure?

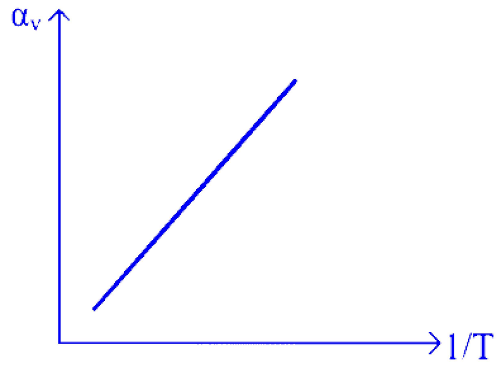
KCET 2021

Options:

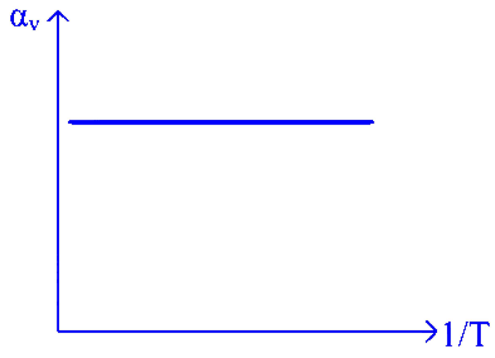
A.



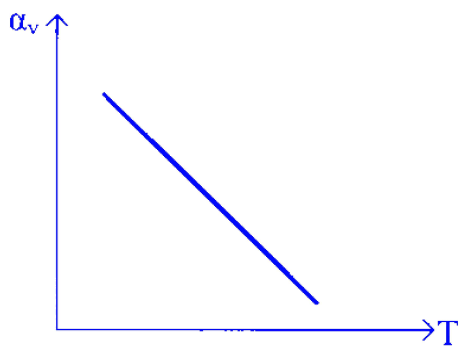
B.



C.



D.



Answer: B

Solution:

Volume expansion is the expansion of volume of a gas due to increase in its temperature.

$\therefore$ Coefficient of volume expansion is given as

$\alpha_V = \frac{\Delta V}{V \times \Delta T}$ .... (i)

where, $V =$ real volume of gas,

$\Delta V =$ change in volume

and $\Delta T =$ change in temperature.

From ideal gas equation,

$pV = nRT$ or $T = \frac{pV}{nR}$ .... (ii)

For constant pressure,

$$p\Delta V = nR\Delta T$$
$$\text{or} \quad \frac{\Delta V}{\Delta T} = \frac{nR}{p} \quad \text{.... (iii)}$$

From Eqs. (i) and (iii), we get

$\alpha_V = \frac{nR}{pV} = \frac{1}{T}$ [$\because$ From Eq. (ii)]

Thus, the variation of α_V with temperature is correctly depicted in option (b).

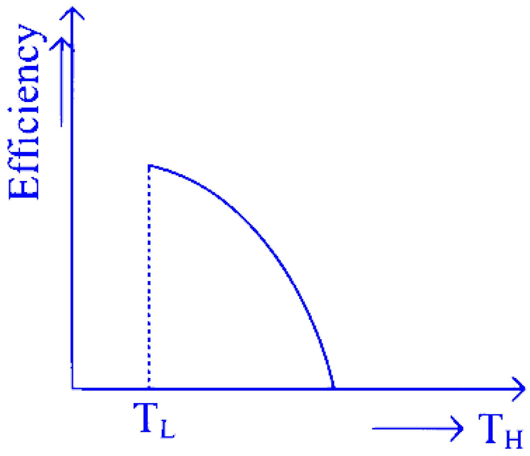
Question13

A number of Carnot engines are operated at identical cold reservoir temperatures (T_L). However, their hot reservoir temperatures are kept different. A graph of the efficiency of the engines versus hot reservoir temperature (T_H) is plotted. The correct graphical representation is

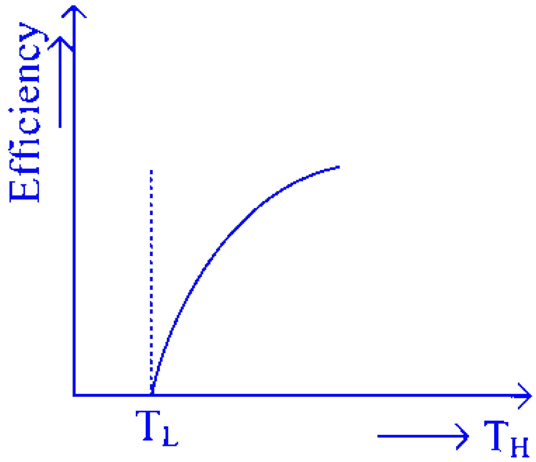
KCET 2021

Options:

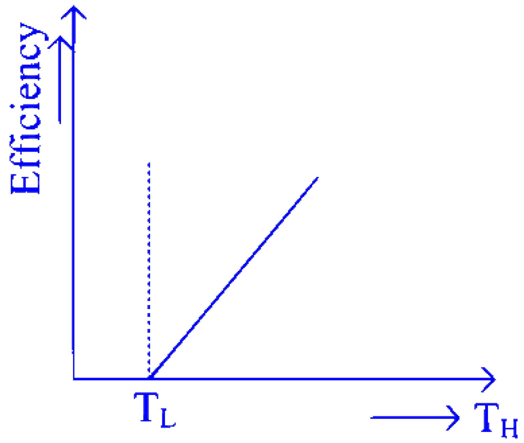
A.



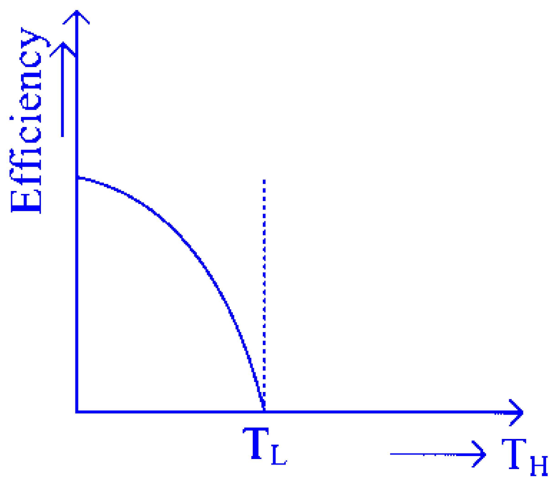
B.



C.



D.



Answer: B

Solution:

Efficiency of a Carnot's engine is given as

$\eta = 1 - \frac{T_L}{T_H}$

where, $T_L =$ temperature of cold reservoir and $T_H =$ temperature of hot reservoir.

At constant T_L, we can say that, with the increase in the value of T_H, η will also increase.

So, the graph between efficiency and T_H is correctly depicted in option (b).

Question14

A gas mixture contains monoatomic and diatomic molecules of 2 moles each. The mixture has a total internal energy of (symbols have usual meanings)

KCET 2021

Options:

A. 3RT

B. 5RT

C. 8RT

D. 9RT

Answer: C

Solution:

Total internal energy of a gas is given as

$U=\frac{n}{2} f R T$

where, $n=$ number of moles

and $f=$ degree of freedom.

Given, $n_{\text{diatomic}}=n_{\text{monoatomic}}=2$

$$\begin{aligned} \text{As, } f_{\text{monoatomic}} &= 3 \\ f_{\text{diatomic}} &= 5 \\ \Rightarrow U_{\text{monoatomic}} &= \frac{2}{2} \times 3 R T=3 R T \\ U_{\text{diatomic}} &= \frac{2}{2} \times 5 R T=5 R T \end{aligned}$$

$\therefore$ Total internal energy of the mixture of gases,

$$\begin{aligned} U_{\text{total}} &= U_{\text{monoatomic}}+U_{\text{diatomic}} \\ &= 3 R T+5 R T=8 R T \end{aligned}$$

Question15

A sphere, a cube and a thin circular plate all of same material and same mass initially heated to same high temperature are allowed to cool down under similar conditions. Then, the

KCET 2020

Options:

A. plate will cool the fastest and cube the slowest

B. sphere will cool the fastest and cube the slowest

C. plate will cool the fastest and sphere the slowest

D. cube will cool the fastest and plate the slowest

Answer: C

Solution:

The rate of heat transfer is directly proportional to the surface area of body. Since, circular plate has greatest surface area and sphere has least surface area amongst the given three bodies. Hence, when a sphere, a cube and a thin circular plate are allowed to cool down under similar conditions, then the plate will cool the fastest and sphere the slowest.

Question16

In an adiabatic expansion of an ideal gas the product of pressure and volume

KCET 2020

Options:

A. decreases

B. increases

C. remains constant

D. at first increases and then decreases

Answer: A

Solution:

In an adiabatic expansion, internal energy decreases and hence temperature also decreases. Hence, from ideal gas equation,

$pV = nRT$

Since, T decreases.

Hence, pV also decreases.

Question17

A certain amount of heat energy is supplied to a monoatomic ideal gas which expands at constant pressure. What fraction of the heat energy is converted into work?

KCET 2020

Options:

A. 1

B. $\frac{2}{3}$

C. $\frac{2}{5}$

D. $\frac{5}{7}$

Answer: C

Solution:

Suppose Q amount of heat is supplied to monoatomic gas which expands at constant pressure. This heat is then converted into the internal energy and work. According to the first law of thermodynamics,

$$Q = U + W$$
$$\text{or} \quad nC_p\Delta T = nC_V\Delta T + W$$

where, C_p and C_V are the specific heat capacity at constant pressure and volume, respectively.

$\therefore$ The fraction of heat converted to work is given as

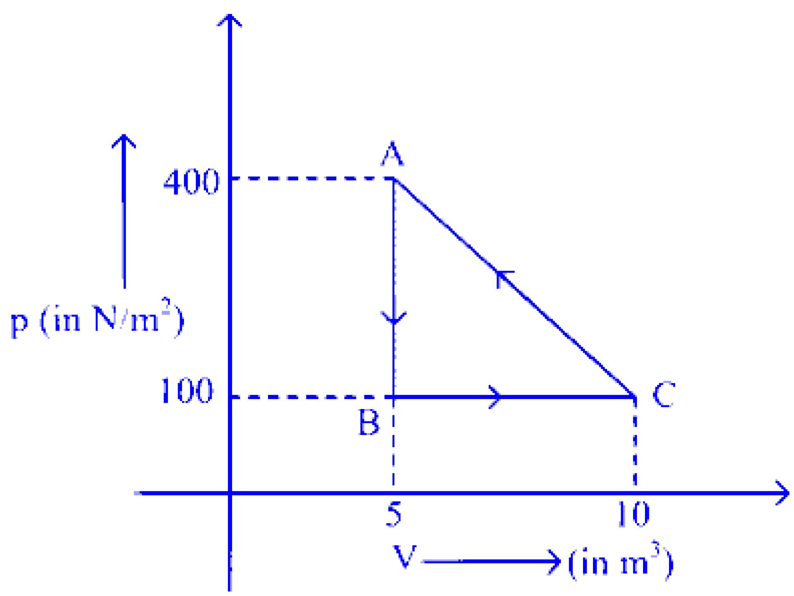
$$\frac{W}{Q} = \frac{nC_p\Delta T - nC_V\Delta T}{nC_p\Delta T}$$

For monoatomic gas, $n = 1$

$$\Rightarrow \quad \frac{W}{Q} = \frac{C_p - C_V}{C_p} = \frac{\frac{5}{2}R - \frac{3}{2}R}{\frac{5}{2}R}$$
$$= \frac{R}{\frac{5}{2}R} = \frac{2}{5}$$

Question18

A thermodynamic system undergoes a cyclic process ABC as shown in the diagram. The work done by the system per cycle is



KCET 2019

Options:

A. 750 J

B. -1250 J

C. -750 J

D. 1250 J

Answer: C

Solution:

Work done by a system in a cyclic process = Area enclose by curve

$$W = \frac{1}{2} \times \Delta P \times \Delta V$$
$$= \frac{1}{2}(100 - 400)(0 - 5) = -750 \text{ J}$$

Question19

One mole of O_2 gas is heated at constant pressure starting at 27°C. How much energy must be added to the gas as to double its volume?

KCET 2019

Options:

A. Zero

B. 450 R

C. 750 R

D. 1050 R

Answer: D

Solution:

As heated at constant. pressure, usingCharle's law $\frac{V_1}{V_2} = \frac{T_1}{T_2}$

here $\quad V_2 = 2V_1, T_1 = 27^\circ = 27 + 273 = 300$ K

$\Rightarrow \quad \frac{1}{2} = \frac{300}{T_2} \Rightarrow T_2 = 600$ K

Now, energy to be added

$$\Delta U = nC_p(T_2 - T_1) = 1 \times \frac{7}{2} \times R \times 300$$
$$= 1050R$$

Question20

A cup of tea cools from $65.5^\circ\mathrm{C}$ to $62.5^\circ\mathrm{C}$ in 1 min in a room at $22.5^\circ\mathrm{C}$. How long will it take to cool from $46.5^\circ\mathrm{C}$ to $40.5^\circ\mathrm{C}$ in the same room?

KCET 2018

Options:

A. 4 min

B. 2 min

C. 1 min

D. 3 min

Answer: A

Solution:

According to Newton's law of cooling, the rate of cooling is proportional to the difference between the object's temperature and the ambient temperature. We can express this relationship with the following equation:

$\frac{\theta_1-\theta_2}{t} = \alpha\left(\frac{\theta_1+\theta_2}{2} - \theta_0\right)$

Where:

θ_1 and θ_2 are the initial and final temperatures respectively

t is the time it takes to cool

α is a constant related to the cooling conditions

θ_0 is the ambient temperature

Given:

For the initial cooling from **65.5°C to 62.5°C** in **1 minute** with an ambient temperature of **22.5°C**, we utilize the formula:

$\frac{65.5-62.5}{1} = \alpha\left(\frac{65.5+62.5}{2} - 22.5\right)$

For cooling from **46.5°C to 40.5°C** in time t, under the same ambient conditions:

$\frac{46.5-40.5}{t} = \alpha\left(\frac{46.5+40.5}{2} - 22.5\right)$

By solving Equations (i) and (ii), we determine the time t for the second stage of cooling. In the calculations shown, we find:

$t = 4$ minutes

Question21

A Carnot engine takes 300 calories of heat from a source at 500 K and rejects 150 calories of heat to the sink. The temperature of the sink is

KCET 2018

Options:

A. 125 K

B. 250 K

C. 750 K

D. 1000 K

Answer: B

Solution:

For a Carnot engine, the ratio of the heat rejected to the heat absorbed is equal to the ratio of the temperatures of the cold sink to the hot source. This relationship is given by:

$\frac{Q_C}{Q_H} = \frac{T_C}{T_H}$

Given:

Heat absorbed, $Q_H = 300$ calories

Heat rejected, $Q_C = 150$ calories

Temperature of the hot source, $T_H = 500$ K

We can substitute these values into the equation:

$\frac{150}{300} = \frac{T_C}{500}$

Simplify the left side:

$\frac{1}{2} = \frac{T_C}{500}$

Now, solve for T_C by multiplying both sides by 500:

$T_C = \frac{500}{2} = 250 \text{ K}$

Therefore, the temperature of the sink is 250 K, which corresponds to:

Option B.

Question22

Pressure of an ideal gas is increased by keeping temperature constant. The kinetic energy of molecules

KCET 2018

Options:

A. decreases

B. increases

C. remains same

D. increases or decreases depending on the nature of gas

Answer: C

Solution:

The kinetic energy of molecules in an ideal gas depends solely on the temperature. When the temperature remains constant, the average kinetic energy also remains constant.

To explain further:

The average kinetic energy per molecule in an ideal gas is given by:

$\langle KE \rangle = \frac{3}{2}kT,$

where:

k is the Boltzmann constant.

T is the temperature in Kelvin.

Even if the pressure increases (which, according to the ideal gas law $PV = nRT$, could happen by compressing the gas or by adding more molecules), as long as the temperature T is held constant, the average kinetic energy $\langle KE \rangle$ remains the same.

Thus, the answer is:

Option C: remains same.

Question23

The S.I. unit of specific heat capacity is

KCET 2017

Options:

A. JK^{-1}

B. Jkg^{-1}

C. $\mathrm{Jmol}^{-1}\,\mathrm{K}^{-1}$

D. $\mathrm{Jkg}^{-1}\,\mathrm{K}^{-1}$

Answer: D

Solution:

The specific heat capacity is defined by the formula

$c = \frac{Q}{m\,\Delta T}$

where:

Q is the heat energy (in Joules),

m is the mass (in kilograms),

ΔT is the temperature change (in Kelvin).

From the formula, you can see that the specific heat capacity has units of energy per unit mass per unit temperature change. This results in units of Joules per kilogram Kelvin, or

$\mathrm{J\,kg^{-1}\,K^{-1}}$.

Thus, the SI unit of specific heat capacity is given by Option D.

Question24

For which combination of working temperatures, the efficiency of Carnot's engine is the least?

KCET 2017

Options:

A. 100 K, 80 K

B. 40 K, 20 K

C. 80 K, 60 K

D. 60 K, 40 K

Answer: A

Solution:

The efficiency of a Carnot engine is determined by the formula:

$\eta = 1 - \frac{T_C}{T_H}$

where:

T_H is the temperature of the hot reservoir.

T_C is the temperature of the cold reservoir.

To find the combination with the least efficiency, we need to calculate η for each option.

Option A: $T_H = 100\,K, T_C = 80\,K$

$\eta_A = 1 - \frac{80}{100} = 1 - 0.8 = 0.2$ or 20%

Option B: $T_H = 40\,K, T_C = 20\,K$

$\eta_B = 1 - \frac{20}{40} = 1 - 0.5 = 0.5$ or 50%

Option C: $T_H = 80\,K, T_C = 60\,K$

$\eta_C = 1 - \frac{60}{80} = 1 - 0.75 = 0.25$ or 25%

Option D: $T_H = 60\,K, T_C = 40\,K$

$\eta_D = 1 - \frac{40}{60} \approx 1 - 0.667 \approx 0.333$ or 33.3%

Comparing the efficiencies, the lowest efficiency is 20% in Option A.

Thus, the combination with the least efficiency is:

Option A: $100\,K,\ 80\,K$.

Question25

The mean energy of a molecule of an ideal gas is

KCET 2017

Options:

A. $\frac{1}{2} KT$

B. $2 KT$

C. KT

D. $\frac{3}{2} KT$

Answer: D

Solution:

For an ideal gas, each translational degree of freedom contributes an average energy of $\frac{1}{2} kT$, where k is the Boltzmann constant. A molecule in three-dimensional space has three translational degrees of freedom. Therefore, the total mean energy per molecule is:

Energy per degree of freedom: $\frac{1}{2} kT$

Total energy for three degrees: $3 \times \frac{1}{2} kT = \frac{3}{2} kT$

Thus, the mean energy of a molecule of an ideal gas is $\frac{3}{2} kT$, which corresponds to Option D.
