Heat and Thermodynamics

Question1

A black body has maximum wavelength ' λ_{m} ' at temperature 2000 K . Its maximum wavelength at 3000 K will be

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Options:

A.

$\frac{3}{2} \lambda_{\mathrm{m}}$

B.

$\frac{16}{81} \lambda_m$

C.

$\frac{81}{16} \lambda_m$

D.

$\frac{2}{3} \lambda_m$

Answer: D

Solution:

We are dealing with **Wien's displacement law**:

$\lambda_m T = \text{constant}$

At temperature $T_1 = 2000$ K, the maximum wavelength is λ_m.

At temperature $T_2 = 3000$ K, the maximum wavelength is λ_m'.

Using Wien's law:

$\lambda_m T_1 = \lambda'_m T_2$

$\lambda'_m = \lambda_m \cdot \frac{T_1}{T_2}$

$\lambda'_m = \lambda_m \cdot \frac{2000}{3000}$

$\lambda'_m = \frac{2}{3}\lambda_m$

✅ **Correct Answer:**

Option D: $\frac{2}{3}\lambda_m$.

Question2

The relation between efficiency (η) of Carnot engine and coefficient of performance (η_1) of refrigerator is

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Options:

A.

$\eta = \frac{1}{1+\eta_1}$

B.

$\eta = \frac{1}{1-\eta_1}$

C.

$\eta = \frac{\eta_1}{1-\eta_1}$

D.

$\eta = \frac{1+\eta_1}{\eta_1}$

Answer: A

Solution:

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

$$\eta_1 = \frac{T_2}{T_1 - T_2} = \frac{\frac{T_2}{T_1}}{\frac{T_1}{T_1} - \frac{T_2}{T_1}} = \frac{1-\eta}{1-(1-\eta)} = \frac{1}{\eta} - 1$$

$$\therefore \quad \frac{1}{\eta} = \eta_1 + 1$$

$$\therefore \quad \eta = \frac{1}{\eta_1 + 1}$$

Question3

500 gram of a diatomic gas is enclosed at a pressure of $10^5 \mathrm{Nm}^{-2}$. The density of the gas is $5 \mathrm{kgm}^{-3}$. The energy of one mole of the gas due to its thermal motion is [consider the gas molecule as a rigid rotator]

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Options:

A.

1.5×10^4 J

B.

2.5×10^4 J

C.

1.5×10^7 J

D.

2.5×10^7 J

Answer: B

Solution:

Energy of one mole of gas due to thermal motion means kinetic energy of the gas per mole, which is given by

$$\text{K.E.} = \frac{f}{2}RT = \frac{f}{2}PV$$

$$V = \frac{\text{Mass}}{\text{Density}} = \frac{500 \times 10^{-3}}{5} = 10^{-1}\ \text{m}^3$$

$$\text{K.E.} = \frac{f}{2}PV \quad \ldots.(f = 5 \text{ for diatomic gas })$$

$$\text{K.E.} = \frac{5}{2}PV = \frac{5}{2} \times 10^5 \times 10^{-1} = 2.5 \times 10^4\ \text{J}$$

Question4

The outer surface of star in the form of a sphere radiates heat as a black body at temperature ' T '. The total radiant energy per unit area, normal to the direction of incidence, received at a distance ' R ' from the centre of a star of radius ' r ' is $(R > r)(\sigma =$ Stefan's constant)

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Options:

A.

$\frac{\sigma \mathrm{r}^2\ \mathrm{T}^4}{\mathrm{R}^2}$

B.

$\frac{\sigma r^2 T^4}{4\pi R^2}$

C.

$\frac{\sigma \mathrm{r}^2\ \mathrm{T}^4}{\mathrm{R}^4}$

D.

$\frac{4\pi\sigma r^2 T^4}{R^2}$

Answer: A

Solution:

Step 1: Total power radiated by the star

The surface flux from a black body at temperature T is

$P_{\text{per unit area}} = \sigma T^4.$

The total surface area of the star:

$A_{\text{star}} = 4\pi r^2.$

So, total radiant power (luminosity) is:

$L = 4\pi r^2 \sigma T^4.$

Step 2: Power distributed over spherical surface at distance R

At distance R, this power is isotropically spread across a sphere of radius R:

$A_R = 4\pi R^2.$

The intensity (power per unit area normal to incidence) is:

$I = \frac{L}{4\pi R^2} = \frac{4\pi r^2 \sigma T^4}{4\pi R^2} = \frac{\sigma r^2 T^4}{R^2}.$

Step 3: Match option

That corresponds to:

Option A:

$$\boxed{\frac{\sigma r^2 T^4}{R^2}}$$

✅ Correct Answer: **Option A**

Question5

A gas having $\gamma = \frac{5}{2}$ and volume 360 c.c. is suddenly compressed to 90 c.c. If the initial pressure of the gas is P , then the final pressure will be

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Options:

A.

$\frac{P}{4}$

B.

8 P

C.

16 P

D.

32 P

Answer: D

Solution:

The process is sudden, implying an adiabatic process

We know for an adiabatic process,

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$
$$\therefore \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = \left(\frac{360}{90}\right)^{\frac{5}{2}} = (4)^{\frac{5}{2}} = 32$$
$$\Rightarrow \frac{P_2}{P} = 32$$
$$\Rightarrow P_2 = 32P$$

Question6

The length of steel rod is 5 cm longer than the copper rod at all temperatures. The length of the steel and copper rod is respectively (Coefficient of linear expansion for steel and copper is respectively $1.1 \times 10^{-5} / {}^{\circ}\mathrm{C}$ and $1.7 \times 10^{-5} / {}^{\circ}\mathrm{C}$)

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Options:

A.

nearly 15 cm and 10 cm

B.

nearly 14 cm and 9 cm

C.

nearly 12 cm and 7 cm

D.

nearly 13 cm and 8 cm

Answer: B

Solution:

Length of steel rod at temp. t $= l_1 + l_1\alpha_1\Delta t$

Length of copper rod at temp. t $= l_2 + l_2\alpha_2\Delta t$

Length of steel rod - length of copper rod $= (l_1 - l_2) + (l_1\alpha_1 - l_2\alpha_2)\Delta t$

For difference in the length to be constant coefficient of Δt must be zero.

$$\begin{aligned} \therefore \quad & l_1\alpha_1 - l_2\alpha_2 = 0 \\ \Rightarrow \quad & l_1\alpha_1 = l_2\alpha_2 \\ \Rightarrow \quad & l_1 \times 1.1 \times 10^{-5} = l_2 \times 1.7 \times 10^{-5} \\ \Rightarrow \quad & 11 l_1 = 17 l_2 \end{aligned}$$

It is given that $l_1 - l_2 = 5$ cm

Solving for l_1 and l_2 from (i) and (ii), we get $l_1 \approx 14$ cm and $l_2 \approx 9$ cm respectively

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Question7

Two spherical black bodies have radii ' R_1 ' and ' R_2 '. Their surface temperatures are ' T_1 ' and ' T_2 '. If they radiate same power, then $\frac{R_2}{R_1}$ is

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Options:

A.

$\frac{T_2}{T_1}$

B.

$\frac{T_1}{T_2}$

C.

$\left(\frac{T_2}{T_1}\right)^2$

D.

$\left(\frac{T_1}{T_2}\right)^2$

Answer: D

Solution:

$$\frac{Q_1}{Q_2} = \left(\frac{R_1}{R_2}\right)^2 \times \left(\frac{T_1}{T_2}\right)^4$$

$\therefore$ for same power,

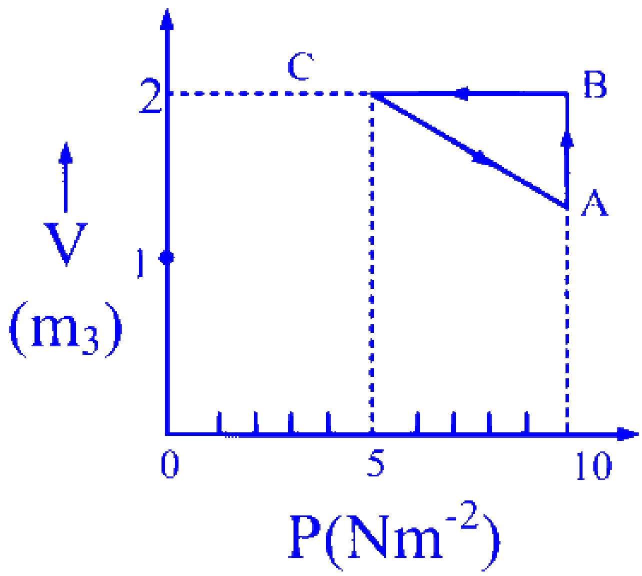
$$\left(\frac{R_1}{R_2}\right)^2 = \left(\frac{T_2}{T_1}\right)^4$$

$$\therefore \left(\frac{R_1}{R_2}\right) = \left(\frac{T_2}{T_1}\right)^2$$

$$\left(\frac{R_2}{R_1}\right) = \left(\frac{T_1}{T_2}\right)^2$$

Question8

An ideal gas taken through a process ABCA as shown in figure. If the net heat supplied to gas in the cycle is 5 J , then the work done by the gas in process from C to A is



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Options:

A.

-5 J

B.

-10 J

C.

-15 J

D.

-20 J

Answer: A

Solution:

Process ABCA is cyclic,

$\Delta \mathrm{U} = 0$

Using first law of thermodynamics,

$\Delta Q = \Delta W = 5J \qquad \ldots (i)$

From the graph,

$$W_{AB} = P\Delta V = 10(2-1) = 10 \quad \ldots(ii)$$
$$W_{BC} = P\Delta V = P(0) = 0 \quad \ldots(iii)$$

Total work done,

$$W = W_{AB} + W_{BC} + W_{CA}$$
$$5J = 10 + 0 + W_{CA} \quad \ldots[\text{ From (i), (ii) and (iii) }]$$

$W_{CA} = -5$ J

Question9

A calorimeter contains 10 g of water at 20°C. The temperature fall to 15°C in 10 min . When calorimeter contains 20 g of water at 20°C , it takes 15 min . for the temperature to become 15°C. The water equivalent at the calorimeter is

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Options:

A.

50 g

B.

25 g

C.

10 g

D.

5 g

Answer: C

Solution:

Let the water equivalent of the calorimeter be x grams. This means the calorimeter acts like it contains x grams of water for heat calculations.

Formula: The way the temperature of water falls is given by:$m\,c\,\frac{dT}{dt} = -k\left[\frac{T_1+T_2}{2} - T_o\right]$where m is the total mass (water + calorimeter equivalent), c is specific heat, T_1 and T_2 are starting and ending temperatures, and T_o is the air temperature outside.

First case (10 g water):

$(10+x)c\frac{(20-15)}{10} = -k\left[\frac{20+15}{2} - T_o\right]$

Second case (20 g water):

$(20+x)c\frac{(20-15)}{15} = -k\left[\frac{20+15}{2} - T_o\right]$

The bracketed factor on the right is the same in both cases. The left side is different because of the different amounts of water and time.

Setting the left sides as equal ratios:

$\frac{10+x}{10} = \frac{20+x}{15}$

Cross-multiplied, this gives:$15(10+x) = 10(20+x)$

Expand:$150 + 15x = 200 + 10x$

Move $10x$ to the left and 150 to the right:$15x - 10x = 200 - 150$

$5x = 50$

So, $x = 10$ grams.

The water equivalent of the calorimeter is 10 grams.

Question10

Two cylinders A and B fitted with piston contain equal amount of an ideal diatomic gas at temperature T K. The piston of cylinder A is free to move while that of cylinder B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise of temperature of the gas in A is $\mathrm{dT_A}$, then the rise in temperature of the gas in B is $\left(\gamma = \frac{C_p}{C_v}\right)$

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Options:

A. $\frac{\mathrm{dT_A}}{2}$

B. $\frac{dT_A}{\gamma}$

C. γdT_A

D. $2dT_A$

Answer: C

Solution:

Step 1: Recall specific heats for diatomic ideal gas

For a diatomic gas (ignoring vibrational d.o.f. at moderate temperatures):

$C_v = \frac{5}{2}R, \quad C_p = C_v + R = \frac{7}{2}R$

$\gamma = \frac{C_p}{C_v} = \frac{7/2}{5/2} = \frac{7}{5}$

Step 2: Heat supplied in each case

- For cylinder A (isobaric):

$Q = nC_p dT_A$

- For cylinder B (isochoric) with temperature rise dT_B:

$Q = nC_v dT_B$

Since Q is the same in both cases:

$nC_p dT_A = nC_v dT_B$

Step 3: Relating temperature rises

$dT_B = \frac{C_p}{C_v} dT_A = \gamma\, dT_A$

Final Answer:

The rise in temperature of the gas in B is

$\boxed{\gamma\, dT_A}$

Correct option: C

Question11

A black sphere has radius R whose rate of radiation is E at temperature T . If radius is made R / 2 and temperature 3T, the rate

of radiation will be

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Options:

A. $\frac{3E}{2}$

B. $\frac{27E}{8}$

C. $\frac{81E}{4}$

D. $\frac{9E}{4}$

Answer: C

Solution:

Step 1: Formula for power radiated

The rate of radiation (power) from a body is given by **Stefan–Boltzmann law**:

$P = \sigma A T^4$

where

- σ = Stefan–Boltzmann constant,
- A = surface area of the sphere,
- T = absolute temperature.

For a sphere of radius R:

$A = 4\pi R^2.$

So,

$E = \sigma(4\pi R^2)T^4.$

Step 2: New situation

Radius is halved: $R' = \frac{R}{2}.$

Temperature is tripled: $T' = 3T.$

So new power is

$E' = \sigma \cdot (4\pi(R/2)^2) \cdot (3T)^4.$

Step 3: Simplify

$E' = \sigma \cdot 4\pi \cdot \frac{R^2}{4} \cdot 81T^4 = \sigma \cdot \pi R^2 \cdot 81T^4.$

Original was

$E = \sigma(4\pi R^2)T^4.$

So

$\frac{E'}{E} = \frac{\sigma\pi R^2 \cdot 81T^4}{\sigma(4\pi R^2)T^4} = \frac{81}{4}.$

Hence,

$E' = \frac{81}{4}E.$

✅ **Final Answer:**

$$\boxed{\frac{81E}{4}}$$

That corresponds to **Option C**.

Question12

In the thermodynamic processes, which of the following statements is NOT true?

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Options:

A.

In an isothermal process, the temperature remains constant.

B.

In an adiabatic process, the system is insulated from surroundings.

C.

In an isochoric process, pressure remains constant.

D.

In an adiabatic process, $PV^{\gamma} = \text{constant}$.

Answer: C

Solution:

We are asked which statement is **NOT true** among the four given:

Option A:

"In an isothermal process, the temperature remains constant."

✓ True. By definition, **isothermal** means constant temperature.

Option B:

"In an adiabatic process, the system is insulated from surroundings."

✓ True. In an adiabatic process, no heat transfer occurs, which can be achieved by insulation.

Option C:

"In an isochoric process, pressure remains constant."

✗ This is **not true**.

In an **isochoric** process, **volume** remains constant (not pressure). Pressure may change as temperature or other conditions change.

Option D:

"In an adiabatic process, $PV^{\gamma} = \text{constant}$."

✓ True, for a reversible adiabatic process in an ideal gas.

✅ **Correct Answer: Option C**

Question13

In case of free expansion, which one of the following statements is WRONG?

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Options:

A. It is an instantaneous change.

B. The system is not in thermodynamic equilibrium.

C. Free expansion can be plotted on a P-V diagram.

D. It is an uncontrolled change.

Answer: C

Solution:

- Free expansion = expansion of a gas into a vacuum without external pressure.
- It happens spontaneously (uncontrolled, irreversible).
- During free expansion, the system is not in thermodynamic equilibrium, because pressure and temperature inside may not be uniform.
- Since it is highly irreversible, it cannot be represented by a well-defined path on a $P–V$ diagram (only initial and final states are meaningful).

Options analysis:

- **A. It is an instantaneous change.**

  → Yes, practically it happens suddenly (instantaneous). Correct statement.

- **B. The system is not in thermodynamic equilibrium.**

  → Correct, because it's an irreversible and non-equilibrium process.

- **C. Free expansion can be plotted on a P–V diagram.**

  → Wrong. Only equilibrium (quasi-static) processes can be represented as a continuous path. For free expansion, only initial and final points can be marked, not the path.

- **D. It is an uncontrolled change.**

  → Correct, free expansion is uncontrolled and irreversible.

✅ **Answer: Option C is WRONG.**

Question14

An ideal gas expands adiabatically, $(\gamma = 1.5)$. To reduce the r.m.s. velocity of the molecules 4 times, the gas has to be expanded

Options:

A. 256 times

B. 128 times

C. 64 times

D. 8 times

Answer: A

Solution:

Since r.m.s. velocity $v \propto \sqrt{T}$,

$\therefore \quad \frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} \qquad \ldots(i)$

Given the r.m.s. velocity is reduced four times.

$\Rightarrow \quad v_2 = \frac{v_1}{4}$

Substituting the above result in (i),

$\Rightarrow \quad \frac{1}{4} = \sqrt{\frac{T_2}{T_1}} \Rightarrow \frac{T_1}{T_2} = 16 \qquad \ldots(ii)$

For adiabatic expansion, $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$$\therefore \quad \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{T_1}{T_2} = 16 \quad \ldots[\text{From(ii)}]$$
$$\Rightarrow \quad \left(\frac{V_2}{V_1}\right)^{1.5-1} = 16$$
$$\therefore \quad \left(\frac{V_2}{V_1}\right)^{0.5} = 16 \Rightarrow \frac{V_2}{V_i} = 256$$

The gas has to be expanded 256 times.

Question15

The temperature at which oxygen molecules will have same r.m.s. speed as helium molecules at $57^{\circ}\mathrm{C}$ is (molecular masses of oxygen and helium are 32 and 4 respectively.)

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Options:

A. 1320 K

B. 2240 K

C. 2640 K

D. 3230 K

Answer: C

Solution:

Step 1: Recall the formula for root mean square (r.m.s.) speed

$$v_{\text{rms}} = \sqrt{\frac{3kT}{m}}$$

where k = Boltzmann constant, T = absolute temperature, m = mass of one molecule.

Equivalently, with molar mass M:

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

where R = universal gas constant and M is molar mass.

Step 2: Equating r.m.s. speeds

For helium at temperature T_{He} and oxygen at T_{O2} :

$$\sqrt{\frac{3RT_{\text{He}}}{M_{\text{He}}}} = \sqrt{\frac{3RT_{\text{O2}}}{M_{\text{O2}}}}$$

Squaring and simplifying:

$$\frac{T_{\text{He}}}{M_{\text{He}}} = \frac{T_{\text{O2}}}{M_{\text{O2}}}$$

$$T_{\text{O2}} = T_{\text{He}} \cdot \frac{M_{\text{O2}}}{M_{\text{He}}}$$

Step 3: Substitute values

- $T_{\text{He}} = 57°\text{C} = 57 + 273 = 330$ K.
- $M_{\text{He}} = 4, M_{\text{O2}} = 32.$

$$T_{\text{O2}} = 330 \cdot \frac{32}{4} = 330 \cdot 8 = 2640 \text{ K}$$

✅ **Final Answer:**

2640 K

Correct Option: **C**.

Question16

Two black spheres P&Q have radii in the ratio $4:3$. The wavelength of maximum intensity of radiation are in the ratio $4:5$ respectively. The ratio of radiated power by P to Q is

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Options:

A. $\frac{625}{144}$

B. $\frac{125}{81}$

C. $\frac{25}{9}$

D. $\frac{5}{3}$

Answer: A

Solution:

Wien's Displacement Law:

$$\lambda_{\max} \propto \frac{1}{\mathrm{T}}$$
$$\Rightarrow \frac{\mathrm{T_P}}{\mathrm{T}_Q} = \frac{\lambda_{\max Q}}{\lambda_{\max,\mathrm{P}}} = \frac{5}{4}$$

By Stefan - Boltzmann Law

Power radiated by a black body

$$P = \sigma A T^4 = \sigma\left(4\pi R^2\right)T^4$$
$$\Rightarrow \quad P \propto R^2 T^4$$
$$\therefore \quad \frac{P_P}{P_Q} = \left(\frac{R_P}{R_Q}\right)^2\left(\frac{T_P}{T_Q}\right)^4 = \frac{16}{9} \times \frac{625}{256} = \frac{625}{144}$$

$\therefore$ The ratio of radiated power by P to Q is $\frac{625}{144}$

Question17

The heat energy that must be supplied to 14 gram of nitrogen at room temperature to raise its temperature by $48^{\circ}\mathrm{C}$ at constant pressure is (Molecular weight of nitrogen $= 28$, $R =$ gas constant, $\mathrm{C_p} = \frac{7}{2}\mathrm{R}$ for diatomic gas)

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Options:

A. 76 R

B. 84 R

C. 90 R

D. 96 R

Answer: B

Solution:

Step 1: Recall formula for heat at constant pressure

$Q = nC_p\Delta T$

where

- $n = \frac{m}{M}$ = number of moles,
- $C_p = \frac{7}{2}R$ for diatomic gas,
- $\Delta T = 48\,K$.

Step 2: Calculate number of moles

Molecular weight of nitrogen (N_2) $M = 28$.

Mass given $m = 14\,g$.

$n = \frac{14}{28} = 0.5\,\mathrm{mol}$

Step 3: Substitute into equation

$Q = nC_p\Delta T = (0.5)\left(\frac{7}{2}R\right)(48)$

Step 4: Simplify

$Q = 0.5 \times \frac{7}{2} \times 48\,R$

$Q = \frac{7}{4} \times 48\,R$

$Q = 7 \times 12\,R = 84R$

✅ **Final Answer: Option B (84 R)**

Question18

The difference in length between two rods A and B is 60 cm at all temperatures. If $\alpha_{\mathrm{A}} = 18 \times 10^{-6}/^{\circ}\mathrm{C}$ and $\alpha_{\mathrm{B}} = 27 \times 10^{-6}/^{\circ}\mathrm{C}$, then the length of $\mathrm{rod\,A}$ and $\mathrm{rod\,B}$ at $0^{\circ}\mathrm{C}$ is respectively

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Options:

A. $l_{\mathrm{A}} = 120$ cm, $l_{\mathrm{B}} = 60$ cm.

B. $l_{\mathrm{A}} = 180$ cm, $l_{\mathrm{B}} = 120$ cm.

C. $l_{\mathrm{A}} = 240$ cm, $l_{\mathrm{B}} = 180$ cm.

D. $l_{\mathrm{A}} = 270$ cm, $l_{\mathrm{B}} = 210$ cm.

Answer: B

Solution:

Given:

$\Delta l = 60$ cm, $\alpha_{\mathrm{A}} = 18 \times 10^{-6}/^{\circ}\mathrm{C}$,
$\alpha_{\mathrm{B}} = 27 \times 10^{-6}/^{\circ}\mathrm{C}$

Δl is constant at all temperatures.

We know $\Delta l = l\alpha\Delta \mathrm{t}$

Let the length of the rods at a temperature 0°C be l_A and l_B

$\therefore$ At temperature $t^\circ\text{C}$

$$l_\text{A}\alpha_\text{A}\text{t}_\text{A} = l_\text{B}\alpha_\text{B}\text{t}_\text{B}$$
$$l_\text{A}(18) \times 10^{-6} = l_\text{B}(27) \times 10^{-6} \quad \ldots(i)$$
$$\Delta l = l_\text{A} - l_\text{B}$$
$$\Delta l = \tfrac{3}{2}l_\text{B} - l_\text{B} \quad \text{...[from (i)]}$$
$$\Delta l = \tfrac{1}{2}l_\text{B}$$
$\therefore$ $l_\text{B} = 2N$

$\therefore$ $l_\text{B} = 2 \times 60 = 120 \text{ cm}$

$\therefore$ $l_\text{A} = \frac{3}{2} \times 120 = 180 \text{ cm}$

Question19

The initial average kinetic energy of the molecules was E , when a gas sample is at 27°C. When the gas is heated to 327°C, then the final average kinetic energy will be

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Options:

A. $\sqrt{2}\text{E}$

B. 2 E

C. 300 E

D. 327 E

Answer: B

Solution:

Initial temperature $\text{T}_1 = 27^\circ\text{C} = 27 + 273 = 300 \text{ K}$

Final temperature $\text{T}_2 = 327^\circ\text{C} = 327 + 273 = 600 \text{ K}$

Average kinetic energy of an ideal gas molecule is directly propartional to the abosulate temperature T .

$$\text{KE} \propto \text{T}$$
$$\therefore \quad \frac{\text{KE}_2}{\text{KE}_1} = \frac{\text{T}_2}{\text{T}_1} \Rightarrow \frac{\text{KE}_2}{\text{KE}_1} = \frac{600}{300}$$
$$\therefore \quad \frac{\text{KE}_2}{\text{KE}_1} = 2$$
$$\therefore \quad \frac{\text{KE}_2}{\text{E}} = 2$$
$$\therefore \quad \text{KE}_2 = 2\text{E}$$

Question20

A sample of an ideal gas $\left(\gamma = \frac{5}{3}\right)$ is heated at constant pressure. If 100 J of heat is supplied to the gas, the work done by the gas is

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Options:

A. 150 J

B. 60 J

C. 40 J

D. 250 J

Answer: C

Solution:

For constant pressure,

Using first law of thermodynamics,

$$\text{W} = \text{Q} - \Delta\text{U}$$
$$\text{W} = \text{mC}_\text{p}\Delta\text{ T} - \text{mC}_\text{v}\Delta\text{ T}$$

For monoatomic gas $\gamma = \frac{\text{C}_\text{p}}{\text{C}_\text{v}} = \frac{5}{3}$

$$\Rightarrow \quad C_v = \frac{3}{5}C_p$$
$$\therefore \quad W = mC_p\Delta T - m\left(\frac{3}{5}C_p\right)\Delta T$$
$$\therefore \quad W = \frac{2}{5}mC_p\Delta T = \frac{2}{5} \times Q \Rightarrow W = \frac{2}{5} \times 100$$
$$\therefore \quad W = 40J$$

Question21

A balloon is filled at $27^\circ\mathrm{C}$ and 1 atmospheric pressure by volume $500\ \mathrm{m}^3$ helium gas. At $-3^\circ\mathrm{C}$ and 0.5 atmospheric pressure, the volume of helium gas will be

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Options:

A. $500\ \mathrm{m}^3$

B. $700\ \mathrm{m}^3$

C. $900\ \mathrm{m}^3$

D. $1000\ \mathrm{m}^3$

Answer: C

Solution:

Initial temperture $(\mathrm{T}_1) = 27^\circ\mathrm{C} = 300\ \mathrm{K}$

Final temperature $(\mathrm{T}_2) = -3^\circ\mathrm{C} = 270\ \mathrm{K}$

From combined Gas Law,

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Substituting values:

$\therefore \quad \frac{1\times500}{300} = \frac{0.5\times\mathrm{V}_2}{270}$

$\therefore \quad \mathrm{V}_2 = \frac{5\times270}{3\times0.5}$

$\therefore \quad \mathrm{V}_2 = 900\ \mathrm{m}^3$

Question22

The volume of a metal sphere increases by 0.33% when its temperature is raised by $50^\circ\mathrm{C}$. The coefficient of linear expansion of the metal is

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Options:

A. $2.2 \times 10^{-5}/^\circ\text{C}$

B. $6.6 \times 10^{-5}/^\circ\text{C}$

C. $13.2 \times 10^{-5}/^\circ\text{C}$

D. $19.8 \times 10^{-5}/^\circ\text{C}$

Answer: A

Solution:

Step 1: Recall relation between volumetric and linear expansion.

- Volumetric expansion coefficient: $\beta = 3\alpha$

  where α = coefficient of linear expansion.

Relative change in volume:

$\frac{\Delta V}{V} = \beta\Delta T = 3\alpha\Delta T$

Step 2: Express given data.

- Percentage change in volume = $0.33\% = 0.0033$ (in decimal).

So,

$\frac{\Delta V}{V} = 0.0033$

- Temperature rise = $\Delta T = 50^\circ\text{C}$.

Step 3: Use formula.

$0.0033 = 3\alpha(50)$

$0.0033 = 150\alpha$

$\alpha = \frac{0.0033}{150}$

$\alpha = 2.2 \times 10^{-5}/^\circ\text{C}$

✅ Final Answer:

$\boxed{2.2 \times 10^{-5}/^\circ\text{C}}$

Correct option: A

Question23

Heat supplied $dQ =$ increased in internal energy dU is true for

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Options:

A. isothermal process.

B. adiabatic process.

C. isobaric process.

D. isochoric process.

Answer: D

Solution:

Heat supplied $dQ =$ increase in internal energy dU.

From the **First Law of Thermodynamics**:

$dQ = dU + dW$

where $dW = PdV$ is the work done by the system.

- **Isothermal process** (Option A):

  Here $dT = 0$, so $\Delta U = 0$. Thus $dQ = dW$.

  Not equal to only dU. ❌

- **Adiabatic process** (Option B):

  Here $dQ = 0$. So $dU = -dW$. Not equal to only dU. ❌

- **Isobaric process** (Option C):

  Pressure constant. Here $dQ = dU + PdV$. So not just dU. ❌

- **Isochoric process** (Option D):

  Volume constant ($dV = 0 \implies dW = 0$).

So first law $\Rightarrow dQ = dU$. ✅

✅ **Correct answer: Option D — Isochoric process**

Question24

A black body emits radiation of maximum intensity at wavelength ' λ ' at temperature T K. Its corresponding wavelength at temperature 1.5 T K will be

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Options:

A. $\frac{2\lambda}{3}$

B. $\frac{4\lambda}{3}$

C. $\frac{16\lambda}{81}$

D. $\frac{81\lambda}{16}$

Answer: A

Solution:

Step 1: Recall Wien's displacement law

$\lambda_{\max} \; T = \text{constant} \quad (b)$

So,

$\lambda_{\max} \; \propto \frac{1}{T}$.

Step 2: Compare two states

At temperature T,

$\lambda = \frac{b}{T}$.

At temperature $1.5T$, the new wavelength is

$\lambda' = \frac{b}{1.5T}$.

Step 3: Relating λ' and λ

$\lambda' = \frac{b}{1.5T} = \frac{1}{1.5} \cdot \frac{b}{T} = \frac{1}{1.5} \cdot \lambda = \frac{\lambda}{1.5} = \frac{2}{3}\lambda.$

Final Answer:

$\boxed{\frac{2\lambda}{3}}$

Correct Option: A

Question25

A rectangular black body of temperature $127^{\circ}\mathrm{C}$ has surface area $4\ \mathrm{cm} \times 2\ \mathrm{cm}$ and rate of radiation is E . If its temperature is increased by $400^{\circ}\mathrm{C}$ and surface area is reduced to half of the initial value then the rate of radiation is

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Options:

A. 4 E

B. E

C. 2 E

D.

8E

Answer: D

Solution:

Energy radiated from a black body,

$$Q = A\sigma T^4 t$$

$$\therefore \frac{Q_2}{Q_1} = \frac{A_2}{A_1} \times \left(\frac{T_2}{T_1}\right)^4 = \frac{1}{2} \times \left(\frac{800}{400}\right)^4 = 8$$

$$\therefore Q_2 = 8E$$

Question26

The temperature of an ideal gas is increased from 100 K to 400 K . If ' x ' is the root mean square velocity of its molecules at 100 K , r.m.s. velocity becomes

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Options:

A. $\frac{x}{4}$

B. $2x$

C. $3x$

D. $4x$

Answer: B

Solution:

Step 1: Formula for r.m.s. speed of a gas

$v_{rms} = \sqrt{\frac{3kT}{m}}$

where:

- k is Boltzmann constant,
- T is absolute temperature,
- m is mass of one molecule.

Step 2: Relation with temperature

$v_{rms} \propto \sqrt{T}$

Step 3: Ratio of r.m.s. velocities

Let the r.m.s. velocity at $T_1 = 100$ K be x. At that point:

$v_1 = x$

At $T_2 = 400$ K:

$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{400}{100}} = \sqrt{4} = 2$

So,

$v_2 = 2x$

✅ **Final Answer:**

Option B: $2x$

Question27

According to the kinetic theory of gases, when two molecules of a gas collide with each other then

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Options:

A. both kinetic energy and momentum are conserved.

B. neither kinetic energy nor momentum is conserved.

C. momentum is conserved but kinetic energy is not conserved.

D. kinetic energy is conserved but momentum is not conserved.

Answer: A

Solution:

According to the **kinetic theory of gases**, molecular collisions are assumed to be **perfectly elastic**.

- In an **elastic collision**, both **kinetic energy** and **momentum** are conserved.
- This assumption is crucial for deriving the **Maxwell-Boltzmann distribution** and gas laws.

✅ **Correct Answer: Option A**

Both kinetic energy and momentum are conserved.

Question28

During the isothermal expansion, a confined ideal gas does $(-150)\mathrm{J}$ of work against its surroundings. This means that

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Options:

A. 150 J of heat has been added to the gas

B. 150 J of heat has been removed from the gas

C. 300 J of heat has been added to the gas

D. no heat is transferred because the process is isothermal

Answer: B

Solution:

Step 1: Recall the First Law of Thermodynamics

$\Delta U = Q - W$

- ΔU = change in internal energy
- Q = heat added to the system
- W = work done by the system

Step 2: Isothermal Expansion of an Ideal Gas

For an ideal gas:

$\Delta U = 0 \quad (\text{since } \Delta U \propto \Delta T, \text{and } \Delta T = 0)$

So:

$0 = Q - W \quad \Rightarrow \quad Q = W$

That is, the heat supplied equals the work done by the gas.

Step 3: Interpreting the Signs

The problem states:

> The gas does $(-150\,\text{J})$ of work.

This implies **using the given sign convention**:

- If $W > 0$, work is done *by* the gas.
- If $W < 0$, work is done *on* the gas.

So here $W = -150$ J, meaning **the surroundings do 150 J of work on the gas**.

From:

$Q = W = -150\,\mathrm{J}$

So, $Q < 0$. That means **150 J of heat is removed from the gas**.

✅ **Answer:**

Option B. 150 J of heat has been removed from the gas.

Question29

A body cools from $80^{\circ}\mathrm{C}$ to $50^{\circ}\mathrm{C}$ in 5 min . In the next time of ' t ' in, the body continues to cool from $50^{\circ}\mathrm{C}$ to $30^{\circ}\mathrm{C}$. The total time taken by the body to cool from $80^{\circ}\mathrm{C}$ to $30^{\circ}\mathrm{C}$ is [The temperature of the surroundings is $20^{\circ}\mathrm{C}$.]

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Options:

A. 10 min

B. 7.5 min

C. 15.0 min

D. 12.5 min

Answer: D

Solution:

According to Newton's law of cooling,

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

where $\theta_0=$ temperature of the surroundings.

Situation I: $\frac{80-50}{5}=K\left(\frac{80+50}{2}-20\right)$

$\frac{30}{5}=K(45) \qquad \ldots(i)$

Situation II: $\frac{50-30}{\mathrm{t}}=\mathrm{K}\left(\frac{50+30}{2}-20\right)$

$\frac{20}{t} = K(20) \qquad \ldots(ii)$

Dividing equation (i) by equation (ii), we get

$$\frac{30}{5} \times \frac{t}{20} = \frac{45}{20}$$
$$t = \frac{45 \times 5}{30}$$
$$\therefore \quad t = 7.5\text{mins}$$

$\therefore$ Total time taken from $80^\circ\mathrm{C}$ to $30^\circ\mathrm{C}$

$= 7.5 + 5 = 12.5\text{mins}$

Question30

The volume of given mass of a gas is increased by 7% at constant temperature. The pressure should be increased by

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Options:

A. 7%

B. 14%

C. 7.52%

D. 14.52%

Answer: A

Solution:

According to Boyle's Law, PV = constant

$P_1V_1 = P_2V_2$

$V_2 = 1.07\ V_1 \quad \ldots.(\because V_2$ is 7% more than $V_1)$

$$P_1V_1 = P_2 \times (1.07V_1)$$
$$\therefore P_1 = \frac{P_2 \times 1.07V_1}{V_1}$$

$$P_2 = \frac{P_1}{1.07} = 0.934P_1$$

$\therefore$% Increase in pressure

$$= \frac{\text{final pressure - initial pressure}}{\text{initial pressure}} \times 100$$

$$= \frac{0.934P_1 - P_1}{P_1} \times 100$$

$$= 0.065 \times 100 = 6.5\%$$

Question31

A monoatomic ideal gas is compressed adiabatically to $\left(\frac{1}{27}\right)$ of its initial volume. If initial temperature of the gas is ' T ' K and final temperature is ' xT ' K , the value of ' x ' is

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Options:

A. 7

B. 9

C. 11

D. 13

Answer: B

Solution:

For an adiabatic process $\mathrm{TV}^{\gamma-1} = \text{constant}.$

$$\therefore \quad \frac{\mathrm{T}_2}{\mathrm{T}_1} = \left(\frac{\mathrm{V}_1}{\mathrm{V}_2}\right)^{\gamma-1}$$

$$= \left(\frac{27}{1}\right)^{\frac{5}{3}-1} \ldots \left(given, \mathrm{V}_2 = \frac{1}{27}\mathrm{V}_1\right)$$

$$\frac{T_2}{T_1} = (27)^{\frac{2}{3}} = 9$$

$\therefore \quad T_2 = 9 \times T_1 \Rightarrow xT_1 = 9 \times T_1$

$\therefore \quad x = 9$

Question32

Select the correct statement.

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Options:

A. The product of pressure and volume of an ideal gas will be equal to translational kinetic energy of the molecules.

B. The temperature of gas is $-73^{\circ}\mathrm{C}$. When the gas is heated to $527^{\circ}\mathrm{C}$, the r.m.s. speed of the molecules is doubled.

C.

The temperature of gas is $-100^{\circ}\mathrm{C}$. When the gas is heated to $+627^{\circ}\mathrm{C}$, the r.m.s. speed of the molecules is four times.

D. The product of pressure and volume of an ideal gas will be equal to half the translational kinetic energy.

Answer: B

Solution:

Checking Translational K.E.:

The formula for translational kinetic energy is Translational K.E. $= \frac{3}{2}\mathrm{PV}$.

This means that options (A) and (D) are wrong, because they do not match this formula.

Finding r.m.s. Speed:

The r.m.s. speed ($\mathrm{v_{rms}}$) is given by $\mathrm{v_{rms}} = \sqrt{\frac{3RT}{\mathrm{M}}}$.

This shows that r.m.s. speed increases as the square root of the temperature: $\mathrm{v_{rms}} \propto \sqrt{\mathrm{T}}$.

Checking Option (C):

For option (C): $T_1 = 100^\circ C$, $T_2 = 627^\circ C$

First, convert to Kelvin:
$T_1 = 100 + 273 = 373\,K$
$T_2 = 627 + 273 = 900\,K$

Calculate the ratio of speeds:

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{373}{900}} = \frac{\sqrt{373}}{30}$$

This means:

$$v_2 = \frac{30}{\sqrt{373}} v_1$$

So, option (C) is not correct.

Checking Option (B):

For option (B): $T_1 = 73^\circ C$, $T_2 = 527^\circ C$

Convert to Kelvin:
$T_1 = 73 + 273 = 346\,K$
$T_2 = 527 + 273 = 800\,K$

Calculate the ratio of speeds:

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{346}{800}} = \frac{1}{2}$$

This means:

$$v_2 = 2v_1$$

So, option (B) is the only correct answer.

Question33

A polyatomic gas at pressure P , having volume ' V ' expands isothermally to a volume ' 3 V ' and then adiabatically to a volume ' 24 V '. The final pressure of gas is (for moderate temperature changes)

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Options:

A. 16 P

B. 24 P

C. P / 36

D. P / 48

Answer: D

Solution:

Step 1: Isothermal Expansion

For isothermal process:

$PV = P_1V_1$

Initial state: P, V.

After isothermal expansion to $3V$:

$P_iV_i = P_1V_1 \implies P \cdot V = P_2 \cdot (3V)$

$P_2 = \frac{P}{3}$

So, after first process:

$(P_2, V_2) = \left(\frac{P}{3}, 3V\right)$.

Step 2: Adiabatic Expansion

Now expand adiabatically from $V_2 = 3V$ to $V_3 = 24V$.

Adiabatic relation:

$PV^\gamma = \text{constant}$.

So:

$P_2\,(V_2^\gamma) = P_3(V_3^\gamma)$.

$P_3 = P_2\left(\frac{V_2}{V_3}\right)^\gamma$.

Substitute:

$P_3 = \frac{P}{3}\left(\frac{3V}{24V}\right)^\gamma = \frac{P}{3}\left(\frac{1}{8}\right)^\gamma$.

Step 3: Value of γ for a Polyatomic Gas

For a polyatomic gas, "moderate temperatures" → assume **non-linear polyatomic molecule**, having $f = 6$ degrees of freedom (3 translational + 3 rotational, neglecting vibrations).

$C_v = \frac{f}{2}R = 3R, \quad C_p = C_v + R = 4R$

$\gamma = \frac{C_p}{C_v} = \frac{4R}{3R} = \frac{4}{3}$.

Step 4: Compute Final Pressure

$P_3 = \frac{P}{3}\left(\frac{1}{8}\right)^{4/3}$.

Now simplify.

$(1/8)^{4/3} = \left(8^{-1}\right)^{4/3} = 8^{-4/3}$.

Since $8 = 2^3$,

$8^{4/3} = (2^3)^{4/3} = 2^4 = 16$.

So:

$(1/8)^{4/3} = \frac{1}{16}$.

Therefore:

$P_3 = \frac{P}{3} \cdot \frac{1}{16} = \frac{P}{48}$.

✅ **Final Answer:**

$\boxed{\frac{P}{48}}$

Correct option: D.

Question34

A stationary object at $4^{\circ}\mathrm{C}$ and weighing 3.5 kg falls from a height of 2000 m on snow mountain at $0^{\circ}\mathrm{C}$. If the temperature of the object just before hitting the snow is $0^{\circ}\mathrm{C}$ and the object comes to rest immediately then the quantity of ice that melts is (Acceleration due to gravity $= 10\ \mathrm{m/s^2}$, Latent heat of ice $= 3.5 \times 10^5\ \mathrm{J/kg}$)

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Options:

A. 2 gram

B. 20 gram

C. 200 gram

D. 2 kg

Answer: C

Solution:

Step 1: Calculate potential energy (P.E.)

The object has potential energy because it is 2000 m above the ground. We use the formula:

$\text{P.E.} = mgh$

Here, $m = 3.5\,\text{kg}$ (mass of object), $g = 10\,\text{m/s}^2$ (acceleration due to gravity), $h = 2000\,\text{m}$ (height).

Step 2: Understand energy conversion

When the object falls, its potential energy turns into heat energy, which is used to melt some of the ice. All the energy goes into melting the ice because the object immediately comes to rest.

We set the energy from falling equal to the heat needed to melt M kg of ice:

Latent heat needed $= ML$

Potential energy lost $= mgh$

So, $ML = mgh$

Step 3: Solve for the mass of melted ice (M)

Given latent heat of ice, $L = 3.5 \times 10^5\,\text{J/kg}$.

Plug in the values:

$M \times 3.5 \times 10^5 = 3.5 \times 10 \times 2000$

$M \times 3.5 \times 10^5 = 70,000$

$M = \frac{70,000}{3.5 \times 10^5}$

$M = 0.2\,\text{kg}$

So, $0.2\,\text{kg}$ or 200 grams of ice melts.

Question35

Six molecules of a gas in container have speeds $2\text{ m/s}, 5\text{ m/s}, 3\text{ m/s}, 6\text{ m/s}, 3\text{ m/s}$, and 5 m/s. The r.m.s. speed is

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Options:

A. 4 m/s

B. 1.7 m/s

C. 4.24 m/s

D. 5 m/s

Answer: C

Solution:

$$v_{\text{rms}} = \sqrt{\frac{v_1^2+v_2^2+v_3^2+-v_n^2}{n}}$$

r.m.s. speeds of the 6 gas molecules are given as 2 m/s, 5 m/s, 3 m/s, 6 m/s, 3 m/s and 5 m/s.

$$\mathrm{v}_{\text{rms}} = \sqrt{\frac{2^2+5^2+3^2+6^2+3^2+5^2}{6}}$$
$$\mathrm{v}_{\text{rms}} = \sqrt{\frac{4+25+9+36+9+25}{6}}$$
$$\mathrm{v}_{\text{rms}} = \sqrt{\frac{106}{6}}$$
$$\mathrm{v}_{\text{rms}} = \sqrt{18} = 3\sqrt{2} = 4.24\ \mathrm{m/s}$$

Question36

During thermodynamic process, the increase in internal energy of a system is equal to the w_{0rk} done on the system. Which process does the system undergo?

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Options:

A. Isothermal

B. Adiabatic

C. Isochoric

D. Isobaric

Answer: B

Solution:

1. First law of thermodynamics:

$\Delta U = Q + W_{\text{on}}$

where

- ΔU = change in internal energy,
- Q = heat supplied **to** the system,
- W_{on} = work done **on** the system.

2. Given condition:

$\Delta U = W_{\text{on}}$

Comparing with the first law:

$\Delta U = Q + W_{\text{on}} \implies W_{\text{on}} = Q + W_{\text{on}}$

Cancelling W_{on} :

$Q = 0$

3. Meaning:

If heat transfer $Q = 0$, then the process is **adiabatic**.

✅ **Correct Answer: Option B — Adiabatic**

Question37

How much should the pressure be increased in order to reduce the volume of a given mass of gas by 5% at the constant temperature?

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Options:

A. 5%

B. 10%

C. 5.26%

D. 4%

Answer: C

Solution:

At constant temperature,

$P_1 V_1 = P_2 V_2 \qquad \ldots (i)$

Volume (V_1) is decreased by 5%

$$\therefore \quad V_2 = V_1 - V_1 \left(\frac{5}{100}\right)$$
$$\frac{V_2}{V_1} = \left(1 - \frac{5}{100}\right) = \frac{19}{20}$$
$$\therefore \quad \frac{P_1}{P_2} = \frac{19}{20}$$

Increase in pressure,

$$\therefore \quad P_2 - P_1 = \frac{20}{19} P_1 - P_1$$
$$\therefore \quad P_2 - P_1 = P_1 \frac{1}{19} = P_1 \times 0.0526$$

i.e. pressure should be increased by 5.26% of P_1

Question38

A polyatomic gas is compressed to $\left(\frac{1}{8}\right)^{\text{th}}$ of its volume adiabatically. If its initial pressure is P_0, its new pressure will be [Given, $\frac{C_p}{C_v} = \frac{4}{3}$]

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Options:

A. $6P_0$

B. $2P_0$

C. $8P_0$

D. $16P_0$

Answer: D

Solution:

- A polyatomic gas undergoes adiabatic compression.
- Final volume = $\frac{1}{8}$ of initial volume.
- Pressure relation for adiabatic process:

$PV^{\gamma} = \text{constant}, \quad \gamma = \frac{C_p}{C_v} = \frac{4}{3}.$

Step 1. Set up equation

$P_0 V_0^{\gamma} = PV^{\gamma}$

where final volume $V = \frac{V_0}{8}$.

So,

$P = P_0 \left(\frac{V_0}{V}\right)^{\gamma}.$

Step 2. Substitute values

$\frac{V_0}{V} = \frac{V_0}{V_0/8} = 8.$

So,

$P = P_0 \cdot 8^{\gamma}.$

$\gamma = \frac{4}{3}.$

Thus,

$P = P_0 \cdot 8^{4/3}.$

Step 3. Simplify

$8^{4/3} = \left(8^{1/3}\right)^4 = 2^4 = 16.$

So,

$P = 16P_0.$

✅ **Final Answer:**

$\boxed{16P_0 \quad \text{(Option D)}}$

Question39

The pressure ' P ', volume ' V ' and temperature ' T ' of a gas in a jar ' A ' and the gas in other jar ' B ' is at pressure ' 2 P ', volume ' V '

and temperature ' $\frac{T}{4}$ '. Then the ratio of the number of molecules in jar A and jar B will be

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Options:

A. 1 : 1

B. 1 : 2

C. 2 : 1

D. 4 : 1

Answer: B

Solution:

According to the gas equation, $PV = Nk_B T$ For first sample, we have,

$PV = N_1 k_B T \qquad \ldots(i)$

For the second sample, we have,

$(2P)\left(\frac{V}{4}\right) = N_2 k_B \left(\frac{T}{4}\right)$

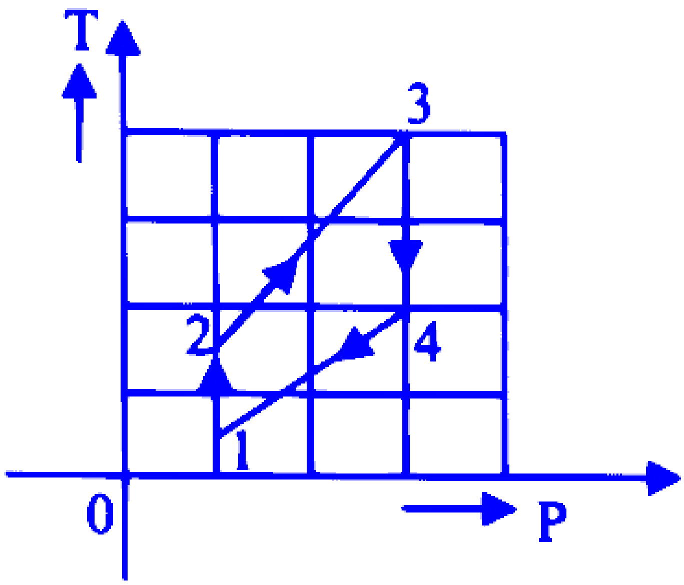
$\Rightarrow \quad PV = \frac{N_2 k_B T}{2} \qquad \ldots(ii)$

$\therefore$ From equations (i) and (ii),

$N_1 = \frac{N_2}{2} \Rightarrow \frac{N_1}{N_2} = \frac{1}{2}$

Question40

Two moles of an ideal monoatomic gas undergo a cyclic process as shown in figure. The temperatures in different states are given as $6\,T_1 = 3\,T_2 = 2\,T_4 = T_3 = 2400\text{ K}$. The work done by the gas during the complete cycle is ($R =$ Universal gas constant)



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Options:

A. -1600 R

B. 1600 R

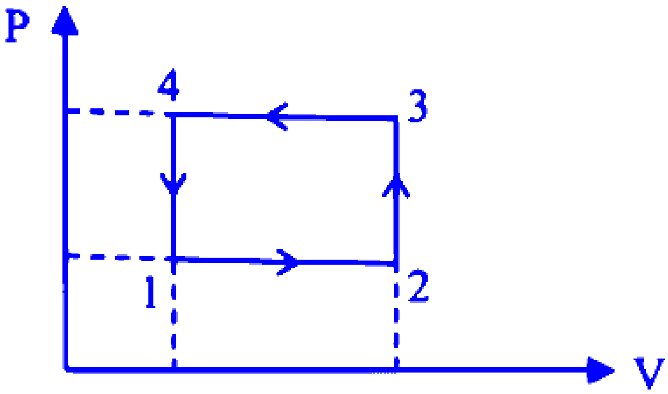
C. -1200 R

D. 800 R

Answer: A

Solution:

The $T-P$ graph provided in the question can be. converted into a $P-V$ diagram as follows:



$1 \rightarrow 2:$ Isobaric process
$2 \rightarrow 3:$ Isochoric process (Work done $= 0$)
$3 \rightarrow 4:$ Isobaric process
$4 \rightarrow 1:$ Isochoric process (Work done $= 0$)
$T_1 = 400\text{ K},\ T_2 = 800\text{ K},$
$T_3 = 2400\text{ K},\ T_4 = 1200\text{ K}$

$$W_{1\rightarrow 2} = P_1(V_2 - V_1) = nR(T_2 - T_1)$$
$$= 2R(800 - 400) = 800R$$
$$W_{3\rightarrow 4} = P_2(V_4 - V_3) = nR(T_4 - T_3)$$
$$= 2R(1200 - 2400) = -2400R$$
$$\therefore \quad W = W_{1\rightarrow 2} + W_{3\rightarrow 4} = -1600R$$

Question41

Two spherical black bodies have radii ' R_1 ' and ' R_2 '. Their surface temperatures are $T_1 K$ and $T_2 K$ respectively. If they radiate the same power, the ratio $\frac{R_1}{R_2}$ is

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Options:

A. $\left(\frac{T_1}{T_2}\right)^4$

B. $\left(\frac{T_1}{T_2}\right)^2$

C. $\left(\frac{T_2}{T_1}\right)^4$

D. $\left(\frac{T_2}{T_1}\right)^2$

Answer: D

Solution:

Step 1: Power radiated by a black body

By Stefan-Boltzmann law:

$P = \sigma A T^4$

where A is surface area of sphere, $A = 4\pi R^2$.

So,

$P = \sigma \cdot (4\pi R^2) \cdot T^4$

$P = 4\pi\sigma R^2 T^4$

Step 2: Equating powers

Given both radiate same power:

$4\pi\sigma R_1^2 T_1^4 = 4\pi\sigma R_2^2 T_2^4$

Canceling constants:

$R_1^2 T_1^4 = R_2^2 T_2^4$

Step 3: Solve for ratio

$\left(\frac{R_1}{R_2}\right)^2 = \left(\frac{T_2}{T_1}\right)^4$

Taking square root:

$\frac{R_1}{R_2} = \left(\frac{T_2}{T_1}\right)^2$

Final Answer:

$\frac{R_1}{R_2} = \left(\frac{T_2}{T_1}\right)^2$

✅ Correct Option: **D**

Question42

A thermometer bulb has volume 10^{-6} m^3 and cross-section of the stem is 0.002 cm^2. The bulb is filled with mercury at $0^\circ\mathrm{C}$. If the thermometer reads temperature as $100^\circ\mathrm{C}$, then the length of mercury column is (coefficient of cubical expansion of mercury $= 18 \times 10^{-5} /{}^\circ\mathrm{C}$)

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Options:

A. 90 cm

B. 9 mm

C. 9 cm

D. 0.9 mm

Answer: C

Solution:

We are tasked with finding the length of the mercury column in the stem after heating the thermometer.

Step 1: Known values

- Volume of mercury bulb:

  $V = 10^{-6}\,\mathrm{m}^3$

- Cross-sectional area of stem:

  $A = 0.002\,\mathrm{cm}^2 = 0.002 \times 10^{-4}\,\mathrm{m}^2 = 2 \times 10^{-7}\,\mathrm{m}^2$

- Temperature rise:

  $\Delta T = 100^\circ\mathrm{C}$

- Cubical expansion coefficient of mercury:

  $\beta = 18 \times 10^{-5}\,/^\circ\mathrm{C}$

Step 2: Change in volume of mercury

$\Delta V = V\beta\Delta T$

$\Delta V = (10^{-6})(18 \times 10^{-5})(100)$

$\Delta V = 18 \times 10^{-9}\,\mathrm{m}^3$

Step 3: Relation to column length

The excess volume enters into the stem of cross-sectional area A, forming a length l:

$\Delta V = A \cdot l$

So:

$l = \frac{\Delta V}{A}$

$l = \frac{18\times10^{-9}}{2\times10^{-7}}$

$l = 0.09\,\mathrm{m} = 9\,\mathrm{cm}$

✅ **Final Answer:**

The length of mercury column is:

9 cm (Option C).

Question43

The two ends of a rod of length ' x ' and uniform cross-sectional area ' A ' are kept at temperatures ' T_1 ' and ' T_2 ' respectively ($\mathrm{T}_1 > \mathrm{T}_2$). If the rate of heat transfer is ' Q/t ', through the rod in steady state, then the coefficient of thermal conductivity ' K ' is

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Options:

A. $\frac{AQ}{\mathrm{tx}(T_1-T_2)}$

B. $\frac{xQ}{tA(T_1-T_2)}$

C. $\frac{xAQ}{t(T_1-T_2)}$

D. $\frac{Q}{\mathrm{txA}(T_1-T_2)}$

Answer: B

Solution:

We are asked about heat conduction through a rod.

The formula for the rate of heat conduction is Fourier's law:

$$\frac{Q}{t} = \frac{KA(T_1-T_2)}{x}$$

Where

- K = thermal conductivity
- A = cross-sectional area
- x = length of the rod
- $(T_1 - T_2)$ = temperature difference

- $\frac{Q}{t}$ = rate of heat flow

Now we rearrange for K:

$K = \frac{\frac{Q}{t} \cdot x}{A(T_1 - T_2)}$

$K = \frac{xQ}{tA(T_1 - T_2)}$

✅ Correct option is:

Option B:

$\frac{xQ}{tA\left(T_1 - T_2\right)}$

Question44

When the pressure of the gas contained in a closed vessel is increased by 2.3%, the temperature of the gas increases by 4 K . The initial temperature of the gas is

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Options:

A. 80 K

B. 150 K

C. 160 K

D. 320 K

Answer: C

Solution:

We are given:

- A closed vessel containing some gas.
- Pressure increases by 2.3%.
- Resulting temperature increases by 4 K.

- We need the initial temperature.

Step 1: Use Ideal Gas Law

For a fixed volume and amount of gas:

$\frac{P}{T} = \text{constant}$

So,

$\frac{P_2}{P_1} = \frac{T_2}{T_1}$.

Step 2: Express the pressure change

Pressure increases by 2.3%, i.e.

$\frac{P_2}{P_1} = 1.023$.

Step 3: Express the temperature change

$T_2 = T_1 + 4$.

So,

$\frac{P_2}{P_1} = \frac{T_1+4}{T_1}$.

Step 4: Write the equation

$1.023 = \frac{T_1+4}{T_1} = 1 + \frac{4}{T_1}$.

Step 5: Solve for T_1

$1.023 - 1 = \frac{4}{T_1}$,

$0.023 = \frac{4}{T_1}$.

$T_1 = \frac{4}{0.023}$.

$T_1 \approx 173.9\,\text{K}$.

Step 6: Match to options

Closest option is **160 K (Option C)**.

✅ **Final Answer: 160 K (Option C)**

Question45

Black bodies A and B radiate maximum energy with wavelength difference 4μ m. The absolute temperature of body A is 3 times that

of B. The wavelength at which body B radiates maximum energy is

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Options:

A. 4μ m

B. 6μ m

C. 2μ m

D. 8μ m

Answer: B

Solution:

Black bodies A and B radiate maximum energy with wavelength difference $4 \mu m$.

Temperatures are related:

$T_A = 3T_B$

We need the wavelength at which body B radiates maximum energy.

Step 1: Use Wien's displacement law

$\lambda_{\max} \; T = b \quad \text{(Wien's constant)}$

So:

$\lambda_A T_A = \lambda_B T_B$

$\lambda_A (3T_B) = \lambda_B T_B$

$\lambda_A = \frac{\lambda_B}{3}$

Step 2: Use the wavelength difference condition

They differ by $4 \mu m$:

$\lambda_B - \lambda_A = 4$

Substitute $\lambda_A = \frac{\lambda_B}{3}$:

$\lambda_B - \frac{\lambda_B}{3} = 4$

$\frac{2}{3} \lambda_B = 4$

$\lambda_B = 6\,\mu m$

✅ **Final Answer**

The wavelength at which body B radiates maximum energy is

$\boxed{6\,\mu m}$

Correct Option: B

Question46

A monoatomic ideal gas, initially at temperature T_1 is enclosed in a cylinder fitted with massless, frictionless piston. By releasing the piston suddenly, the gas is allowed to expand adiabatically to a temperature T_2. If L_1 and L_2 are the lengths of the gas columns before and after expansion respectively, then (T_2/T_1) is given by

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Options:

A. $\frac{\mathrm{L}_1}{\mathrm{L}_2}$

B. $\frac{\mathrm{L}_2}{\mathrm{L}_1}$

C. $\left(\frac{\mathrm{L}_1}{\mathrm{L}_2}\right)^{2/3}$

D. $\left(\frac{L_2}{L_1}\right)^{2/3}$

Answer: C

Solution:

Adiabatic process formula:

For an adiabatic process, the following formula holds:
$\mathrm{TV}^{\gamma-1} = \text{constant}$This means:
$\frac{\mathrm{T}_2}{\mathrm{T}_1} = \left(\frac{\mathrm{V}_1}{\mathrm{V}_2}\right)^{\gamma-1}$

Value of γ for monoatomic gas:

For a monoatomic gas, $\gamma = \frac{5}{3}$.

Calculate $\gamma - 1$:

$\gamma - 1 = \frac{5}{3} - 1 = \frac{2}{3}$

Relating volume to length:

The volume of gas is calculated as the area (A) of the cylinder times the length (L) of the gas column. So, $V_1 = AL_1$ and $V_2 = AL_2$.

Substitute in the temperature formula:

Now, substitute these volumes into the earlier formula:
$\frac{T_2}{T_1} = \left(\frac{AL_1}{AL_2}\right)^{2/3}$ The area (A) cancels out: $\frac{T_2}{T_1} = \left(\frac{L_1}{L_2}\right)^{2/3}$

Final result:

So, the ratio of the final and initial temperature is:
$\frac{T_2}{T_1} = \left(\frac{L_1}{L_2}\right)^{2/3}$

Question47

Two bodies A and B at temperatures ' T_1 ' K and ' T_2 ' K respectively have the same dimensions. Their emissivities are in the ratio $16 : 1$. At $T_1 = xT_2$, they radiate the same amount of heat per unit area per unit time. The value of x is

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Options:

A. 8

B. 4

C. 2

D. 0.5

Answer: D

Solution:

We are asked:

Two bodies, A and B, **same dimensions** (so same surface area).

Temperatures are T_1 and T_2.

Emissivities in the ratio 16 : 1.

At $T_1 = xT_2$, they radiate the same power per unit area per unit time.

Find x.

Step 1: Radiation law

Radiated power per unit area (Stefan–Boltzmann law):

$E = e\sigma T^4$

where e is emissivity.

Step 2: Apply to both bodies

- For body A: emissivity ratio given " 16 : 1". Let emissivity of A = $16k$, B = k.

Then:

$E_A = (16k)\sigma T_1^4,$

$E_B = (k)\sigma T_2^4.$

Step 3: Condition

Same power per unit area:

$16k\sigma T_1^4 = k\sigma T_2^4$

$16T_1^4 = T_2^4$

$\left(\frac{T_1}{T_2}\right)^4 = \frac{1}{16}.$

Step 4: Solve

$\frac{T_1}{T_2} = \left(\frac{1}{16}\right)^{1/4} = \frac{1}{2}.$

So

$x = \frac{1}{2} = 0.5.$

✅ **Answer: Option D (0.5)**

Question48

In an isobaric process of an ideal gas, the ratio of heat supplied and work done by the system $\left(\frac{Q}{W}\right)$ is $\left[\frac{C_P}{C_V}=\gamma\right]$.

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Options:

A. 1

B. γ

C. $\frac{\gamma}{\gamma-1}$

D. $\frac{\gamma-1}{\gamma}$

Answer: D

Solution:

Step 1: Recall expressions

For an **isobaric process**:

- Heat supplied:

$Q=nC_p\Delta T$

- Work done:

$W=P\Delta V$

But also, for an ideal gas:

$P\Delta V=nR\Delta T$

So:

$W=nR\Delta T$

Step 2: Ratio

$\frac{Q}{W}=\frac{nC_p\Delta T}{nR\Delta T}=\frac{C_p}{R}$

Step 3: Simplify in terms of γ

We know the relation:

$C_p - C_v = R$

and

$\gamma = \frac{C_p}{C_v}$

So:

$\frac{C_p}{R} = \frac{C_p}{C_p - C_v} = \frac{\gamma C_v}{(\gamma C_v - C_v)} = \frac{\gamma C_v}{(\gamma - 1) C_v} = \frac{\gamma}{\gamma - 1}$

✅ **Final Answer:**

$\frac{Q}{W} = \frac{\gamma}{\gamma - 1}$

Correct option: (C) $\frac{\gamma}{\gamma - 1}$

Question49

The temperature of a body on Kelvin scale is ' x ' K. When it is measured by a Fahrenheit thermometer, it is found to be ' x ' °F. The value of ' x ' is (nearly)

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Options:

A. 40

B. 313

C. 574

D. 301

Answer: C

Solution:

The temperature of a body on Kelvin scale = x K

On Fahrenheit scale = $x\ {}^{\circ}F$

Find x.

Step 1: Relation between Kelvin and Celsius

$T(^\circ C) = T(K) - 273$

So if $T = x$ K, then $T = x - 273\ ^\circ C$.

Step 2: Relation between Celsius and Fahrenheit

$T(^\circ F) = \frac{9}{5}T(^\circ C) + 32$

So,

$x = \frac{9}{5}(x - 273) + 32$

Step 3: Simplify

$x = \frac{9}{5}x - \frac{9}{5} \cdot 273 + 32$

$x - \frac{9}{5}x = -\frac{9}{5} \cdot 273 + 32$

$\left(1 - \frac{9}{5}\right)x = -\frac{9}{5} \cdot 273 + 32$

$\left(-\frac{4}{5}\right)x = -\frac{2457}{5} + 32$

$\left(-\frac{4}{5}\right)x = -491.4 + 32$

$\left(-\frac{4}{5}\right)x = -459.4$

Step 4: Solve for x

$x = \frac{-459.4 \cdot 5}{-4}$

$x = \frac{2297}{4} \approx 574.25$

Final Answer:

$x \approx 574$

✓ Correct Option: **C (574)**

Question50

For a gas at a particular temperature on an average, the quantity which remains same for all molecules is

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Options:

A. velocity

B. momentum

C. kinetic energy

D. angular momentum

Answer: C

Solution:

According to the kinetic theory of gases, the average kinetic energy (K.E.) of gas molecules is given as:

$$\text{K.E.} = \frac{3}{2}\text{kT}$$

This means that at a given temperature, the average kinetic energy of all gas molecules will be the same.

Question51

If 120 J of thermal energy is incident on area $3\ \mathrm{m}^2$, the amount of heat transmitted is 12 J , coefficient of absorption is 0.6 , then the amount of heat reflected is

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Options:

A. 24 J

B. 30 J

C. 36 J

D. 40 J

Answer: C

Solution:

We are given:

- Thermal energy incident = $Q_{\text{incident}} = 120\,\text{J}$
- Heat transmitted = $Q_{\text{transmitted}} = 12\,\text{J}$
- Coefficient of absorption = $a = 0.6$

Step 1: Absorbed heat

Coefficient of absorption is

$$a = \frac{Q_{\text{absorbed}}}{Q_{\text{incident}}}$$

So,

$$Q_{\text{absorbed}} = a \cdot Q_{\text{incident}} = 0.6 \times 120 = 72\,\text{J}$$

Step 2: Energy conservation

Total incident energy is partitioned as:

$$Q_{\text{incident}} = Q_{\text{absorbed}} + Q_{\text{reflected}} + Q_{\text{transmitted}}$$

So,

$$120 = 72 + Q_{\text{reflected}} + 12$$

$$Q_{\text{reflected}} = 120 - 84 = 36\,\text{J}$$

✅ Answer:

The amount of heat reflected is

36 J

Correct Option: C (36 J)

Question52

When an ideal gas $\left(\gamma = \frac{5}{3}\right)$ is heated under constant pressure, then what percentage of given heat energy will be utilised in doing external work?

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Options:

A. 60%

B. 20%

C. 30%

D. 40%

Answer: D

Solution:

Step 1: Recall relation between Cv, Cp, and γ

$\gamma = \frac{C_p}{C_v}, \quad C_p - C_v = R$

Given:

$\gamma = \frac{5}{3}$

Step 2: Express C_v and C_p in terms of R

$\frac{C_p}{C_v} = \frac{5}{3}$

$C_p = \frac{5}{3} C_v$

And:

$C_p - C_v = R \implies \frac{5}{3} C_v - C_v = R \implies \frac{2}{3} C_v = R$

So:

$C_v = \frac{3}{2} R, \quad C_p = \frac{5}{2} R$

Step 3: Fraction of heat used for work in isobaric process

At constant pressure, if temperature rises by ΔT:

- Heat supplied:

$Q = nC_p \Delta T$

- Work done:

$W = nR\Delta T$

- Fraction used for work:

$\frac{W}{Q} = \frac{nR\Delta T}{nC_p \Delta T} = \frac{R}{C_p}$

Step 4: Substitute values

$\frac{W}{Q} = \frac{R}{\frac{5}{2}R} = \frac{2}{5} = 0.4$

So:

40%

✅ **Final Answer:**

Option D: 40%

Question53

The mean kinetic energy of the molecules of an ideal gas at $399^{\circ}\mathrm{C}$ is ' E '. The temperature at which the mean kinetic energy of its molecules will be ' $\mathrm{E}/2$ ', is

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Options:

A. $336^{\circ}\mathrm{C}$

B. $276^{\circ}\mathrm{C}$

C. $123^{\circ}\mathrm{C}$

D. $63^{\circ}\mathrm{C}$

Answer: D

Solution:

Step 1: Recall the formula

For an ideal gas, the **mean kinetic energy per molecule** is proportional to absolute temperature:

$\langle KE \rangle = \frac{3}{2} k_B T$

So:

$\langle KE \rangle \propto T \quad \text{(in Kelvin)}$

Step 2: Initial conditions

Given that at $T_1 = 399°C$:

$T_1 = 399 + 273 = 672\,K$

The mean kinetic energy $E \propto T_1$.

Step 3: Required condition

We want $E/2$. Since KE is proportional to T:

$\frac{E}{2} \propto \frac{T_1}{2}$

So the required temperature:

$T_2 = \frac{T_1}{2} = \frac{672}{2} = 336\,K$

Step 4: Convert back to Celsius

$T_2(°C) = 336 - 273 = 63°C$

✅ **Final Answer:**

$\boxed{63°C}$

Correct option: D.

Question54

A gas undergoes a change in which its pressure ' P ' and volume ' V ' are related as $PV^n =$ constant, where n is a constant. If the specific heat of the gas in this change is zero, then the value of n is ($\gamma =$ adiabatic ratio)

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Options:

A. $1 - \gamma$

B. $\gamma + 1$

C. $\gamma - 1$

D. γ

Answer: D

Solution:

We are asked:

A gas undergoes a polytropic process given by

$PV^n =$ constant.

The specific heat in this process is zero. We want the value of n in terms of the adiabatic index $\gamma = \frac{C_p}{C_v}$.

Step 1: Recall general formula for specific heat in polytropic process

For any polytropic process $PV^n =$ constant, the **effective molar specific heat** is:

$C = \frac{C_p - nC_v}{1-n}$

Step 2: Condition for zero specific heat

We want $C = 0$. That means:

$\frac{C_p - nC_v}{1-n} = 0$

$C_p - nC_v = 0 \quad \Rightarrow \quad n = \frac{C_p}{C_v} = \gamma.$

Step 3: Verify

Thus, when $n = \gamma$, the specific heat is zero. This has physical meaning: in such a process all heat supplied goes into expansion work, with no temperature change in terms of heat capacity.

Final Answer:

$\boxed{\gamma}$

Correct option: D.

Question55

Hot water cools from $80^\circ \mathrm{C}$ to $60^\circ \mathrm{C}$ in 1 minutes. In cooling from $60^\circ \mathrm{C}$ to $50^\circ \mathrm{C}$ it will take (room temperature $= 30^\circ \mathrm{C}$)

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Options:

A. 48 s

B. 42 s

C. 50 s

D. 45 s

Answer: A

Solution:

Newton's law of cooling tells us how things cool down. It says:

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

Here, θ_1 is the starting temperature, θ_2 is the ending temperature, t is the time taken, K is a constant, and θ_0 is the room temperature.

Step 1: Use the formula for cooling from 80°C to 60°C

Plug in the values: $\frac{80-60}{60} = K\left(\frac{80+60}{2} - 30\right)$

This becomes: $\frac{20}{60} = K(40)$

Simplify: $\frac{1}{3} = K(40) \quad \ldots(i)$

Step 2: Use the formula for cooling from 60°C to 50°C

Plug in the values: $\frac{60-50}{t} = K\left(\frac{60+50}{2} - 30\right)$

This becomes: $\frac{10}{t} = K(25) \quad \ldots(ii)$

Step 3: Divide equation (i) by equation (ii) to find t

Set up the equations:

$\frac{\frac{1}{3}}{K(40)} \div \frac{\frac{10}{t}}{K(25)}$

This simplifies to:

$\frac{1/3}{10/t} = \frac{40}{25}$

$\frac{1}{3} \times \frac{t}{10} = \frac{40}{25}$

Now, solve for t:

$\frac{t}{30} = \frac{40}{25}$

$t = \frac{40}{25} \times 30 = \frac{1200}{25} = 48$ seconds.

Question56

A Carnot engine has efficiency $\frac{1}{6}$. It becomes $\frac{1}{3}$, when the temperature of sink is lowered by

57 K . The temperature of the source is

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Options:

A. 171 K

B. 399 K

C. 342 K

D. 285 K

Answer: C

Solution:

We are given:

- Efficiency of Carnot engine:

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

where T_1 = source temperature, T_2 = sink temperature (both in Kelvin).

Step 1: Use first efficiency condition

$\eta = \frac{1}{6} = 1 - \frac{T_2}{T_1}$

$\frac{T_2}{T_1} = 1 - \frac{1}{6} = \frac{5}{6}$

$T_2 = \frac{5}{6} T_1$

Step 2: Use second efficiency condition

New efficiency $\eta' = \frac{1}{3}$, and new sink temp is $T_2' = T_2 - 57$.

$\frac{1}{3} = 1 - \frac{T_2 - 57}{T_1}$

$\frac{T_2-57}{T_1} = 1 - \frac{1}{3} = \frac{2}{3}$

$T_2 - 57 = \frac{2}{3}T_1$

Step 3: Solve system

From Eqn 1: $T_2 = \frac{5}{6}T_1$.

Substitute into Eqn 2:

$\frac{5}{6}T_1 - 57 = \frac{2}{3}T_1$

$\frac{5}{6}T_1 - \frac{2}{3}T_1 = 57$

$(\frac{5}{6} - \frac{4}{6})T_1 = 57$

$\frac{1}{6}T_1 = 57$

$T_1 = 342\,\mathrm{K}$

✅ **Answer:**

The source temperature is

342 K

Correct Option: C (342 K)

Question57

The r.m.s. speed of gas molecules at 800 K will be

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Options:

A. same as at 200 K

B. twice the value at 200 K

C. four times the value at 200 K

D. half the value at 200 K

Answer: B

Solution:

We need to use the formula for the **root mean square (r.m.s.) speed**:

$$v_{\text{rms}} = \sqrt{\frac{3kT}{m}}$$

So,

$$v_{\text{rms}} \propto \sqrt{T}$$

We are asked to compare v_{rms} at $T = 800\,K$ with that at $T = 200\,K$.

$$\frac{v_{800}}{v_{200}} = \sqrt{\frac{800}{200}} = \sqrt{4} = 2$$

Thus, the r.m.s. speed at 800 K is **twice** the value at 200 K.

✅ **Correct Answer:**

Option B: twice the value at 200 K

Question58

If a black body at 400 K surrounded by atmosphere at 300 K has rate of cooling ' R_0 ', the same body at 900 K , surrounded by same atmosphere, will have rate of cooling nearly

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Options:

A. $4R_0$

B. $16R_0$

C. $36R_0$

D. $\frac{81R_0}{16}$

Answer: C

Solution:

Step 1: Understand Stefan's Law

The rate at which a black body cools depends on the difference between the fourth powers of its temperature and the temperature of its surroundings. This law is written as:Rate $\propto (T^4 - T_0^4)$where T is the temperature of the black body, and T_0 is the temperature of the surroundings.

Step 2: Rate of Cooling for Given Temperatures

Let the temperature of the body in the first case be $T_1 = 400\,\mathrm{K}$, and the temperature of the surroundings $T_0 = 300\,\mathrm{K}$. For the second case, the temperature of the body is $T_2 = 900\,\mathrm{K}$, but T_0 is still $300\,\mathrm{K}$.

Step 3: Formula for Each Case

The rate for the first case:$R_0 = k\left(T_1^4 - T_0^4\right)$The rate for the second case:$R_1 = k\left(T_2^4 - T_0^4\right)$Here, k is a constant.

Step 4: Find the Ratio of Rates

To compare, divide the two rates: $\frac{R_0}{R_1} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4} = \frac{(400)^4 - (300)^4}{(900)^4 - (300)^4}$

Step 5: Simplify and Find the Answer

When you do the calculation, $\frac{R_0}{R_1} = \frac{35}{1296}$ So,$R_1 \approx 36R_0$This means the rate of cooling at 900 K is about 36 times greater than at 400 K.

Question59

The temperature of an ideal gas is increased from 100 K to 400 K . If ' x ' is the R.M.S. velocity of its molecules at 100 K , it becomes

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Options:

A. $\frac{x}{4}$

B. $2x$

C. $3x$

D. $4x$

Answer: B

Solution:

Step 1: Recall formula for RMS velocity

The root-mean-square (RMS) velocity is given by:

$v_{rms} = \sqrt{\frac{3k_BT}{m}}$

So,

$v_{rms} \propto \sqrt{T}$.

Step 2: Compare velocities at two temperatures

If RMS velocity is x at $T_1 = 100\,K$, then:

$x \propto \sqrt{100}$.

At $T_2 = 400\,K$:

$v'_{rms} \propto \sqrt{400}$.

Step 3: Ratio

$\frac{v'_{rms}}{x} = \frac{\sqrt{400}}{\sqrt{100}} = \frac{20}{10} = 2$.

So the new velocity at 400 K = $2x$.

✅ **Final Answer:**

Option B: $2x$

Question60

Heat is given to an ideal gas in an isothermal process. Then

A. internal energy of the gas will decrease.

B. internal energy of the gas will increase.

C. internal energy of the gas will not change.

D. the gas will do negative work.

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Options:

A. B

B. C

C. D

D. A

Answer: B

Solution:

We are dealing with an **isothermal process** for an **ideal gas**.

- For an ideal gas, the **internal energy** depends only on its **temperature.**
- In an isothermal process, temperature remains constant → **internal energy does not change** ($\Delta U = 0$).
- Heat supplied to the gas (Q) is completely converted into **work done by the gas** (W).
- Therefore: $Q = W$, and $\Delta U = 0$.

Now let's check the given options:

A. Internal energy of the gas will decrease. → ❌ (wrong).

B. Internal energy of the gas will increase. → ❌ (wrong).

C. Internal energy of the gas will not change. → ✅ (correct).

D. The gas will do negative work. → ❌ (since gas does **positive** work when it expands).

✓ **Correct Answer: Option B (C: Internal energy of the gas will not change)** ✅

Question61

A rectangular block of surface area A emits energy E per second at $27^\circ C$. If length and breadth is reduced to half of initial value and temperature is raised to $327^\circ C$ then energy emitted per second becomes

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Options:

A. 2 E

B. 4 E

C. E

D. 8 E

Answer: B

Solution:

Let us solve this step-by-step using **Stefan-Boltzmann Law**, which is discussed in your NCERT textbook.

Step 1: Stefan-Boltzmann Law

The power radiated by a body (energy emitted per second) is given by:

$P = \sigma \epsilon A T^4$

where:

- σ = Stefan-Boltzmann constant,
- ϵ = emissivity,
- A = surface area,
- T = absolute temperature in Kelvin.

Step 2: Initial Condition

Let the initial emission be E at 27°C (which is $300\,\text{K}$):

$E = \sigma \epsilon A (300)^4$

Step 3: New Condition

- Length and breadth are reduced to half, so area $A' = \left(\frac{1}{2}\right) \times \left(\frac{1}{2}\right) A = \frac{1}{4} A$
- Temperature is raised to $327^\circ\text{C} = 600\,\text{K}$

The new emission is:

$E' = \sigma \epsilon A' (600)^4 = \sigma \epsilon \left(\frac{A}{4}\right) (600)^4$

Step 4: Find the Ratio

Take the ratio $\frac{E'}{E}$:

$\frac{E'}{E} = \frac{\sigma\epsilon\frac{A}{4}(600)^4}{\sigma\epsilon A(300)^4} = \frac{1}{4}\frac{(600)^4}{(300)^4}$

Since $600 = 2 \times 300$,

$(600)^4 = (2 \times 300)^4 = 2^4 \times (300)^4 = 16 \times (300)^4$

Therefore,

$\frac{E'}{E} = \frac{1}{4} \times \frac{16 \times (300)^4}{(300)^4} = \frac{1}{4} \times 16 = 4$

$E' = 4E$

Final Answer

Option B: $4E$

Question62

When a diatomic gas (rigid) undergoes adiabatic change, its pressure (P) and temperature (T) are related as $P \propto T^c$. The value of c is

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Options:

A. 2.5

B. 3.5

C. 1.5

D. 5.2

Answer: B

Solution:

For a **rigid diatomic gas** (meaning rotation is allowed but vibration is ignored), we proceed as per the NCERT method.

Step 1: Adiabatic Equation

For any adiabatic process:

$PV^\gamma = \text{constant}$

where γ is the adiabatic index.

Step 2: Ideal Gas Law

Also,

$PV = nRT$

So,

$V = \frac{nRT}{P}$

Step 3: Substitute V in adiabatic equation

Substitute V in the adiabatic equation:

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

$P \cdot (nRT)^\gamma \cdot P^{-\gamma} = \text{constant}$

$(nR)^\gamma \cdot P^{1-\gamma} \cdot T^\gamma = \text{constant}$

Since n and R are constants, we can absorb them into the overall constant:

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

$P^{1-\gamma} \propto T^{-\gamma}$

$P \propto T^{\frac{\gamma}{\gamma-1}}$

Step 4: Value of γ for Diatomic Gas

For a diatomic gas (rotational but **not vibrational**):

- Degrees of freedom $= 5$
- $C_v = \frac{5}{2}R$
- $C_p = C_v + R = \frac{7}{2}R$
- $\gamma = \frac{C_p}{C_v} = \frac{7/2}{5/2} = \frac{7}{5} = 1.4$

Step 5: Value of c

$$P \propto T^c \qquad \text{where } c = \frac{\gamma}{\gamma - 1}$$

$\gamma = \frac{7}{5}$

So,

$c = \frac{\gamma}{\gamma-1} = \frac{\frac{7}{5}}{\frac{7}{5}-1} = \frac{\frac{7}{5}}{\frac{2}{5}} = \frac{7}{2} = 3.5$

Correct answer: Option B (3.5)

Question63

For an ideal gas, the density of the gas is ρ_0 when temperature and pressure of the gas are T_0 and P_0 respectively. when the temperature of the gas is $2\ \mathrm{T}_0$, its pressure becomes $3\mathrm{P}_0$. The new density will be

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Options:

A. $\frac{2}{3}\rho_0$

B. $\frac{3}{4}\rho_0$

C. $\frac{4}{3}\rho_0$

D. $\frac{3}{2}\rho_0$

Answer: D

Solution:

Let the mass of the gas be m, and its volume at initial conditions be V_0.

Initial condition:

- Pressure $= P_0$
- Temperature $= T_0$
- Density $= \rho_0$

We know,

$\rho_0 = \frac{m}{V_0}$

Using the ideal gas equation,

$P_0V_0 = nRT_0$

Where n is the number of moles.

$n = \frac{m}{M}$ (where M is the molar mass)

So,

$P_0V_0 = \frac{m}{M}RT_0$

Final condition:

- Pressure $= 3P_0$
- Temperature $= 2T_0$
- Volume $= V$

Again from the ideal gas law,

$3P_0 \cdot V = \frac{m}{M}R \cdot 2T_0$

Solving for V in final condition:

$3P_0V = \frac{m}{M}R \cdot 2T_0$

But from the initial condition,

$P_0V_0 = \frac{m}{M}RT_0 \implies \frac{m}{M}RT_0 = P_0V_0$

So, substitute:

$3P_0V = 2P_0V_0 \implies V = \frac{2}{3}V_0$

Find new density:

$\rho = \frac{m}{V} = \frac{m}{(2/3)V_0} = \frac{3m}{2V_0}$

But $\rho_0 = \frac{m}{V_0}$

So,

$\rho = \frac{3}{2}\rho_0$

Final Answer:

The new density is

$$\boxed{\frac{3}{2}\rho_0}$$

Correct Option: D

Question64

A centigrade and Fahrenheit thermometer are dipped in boiling water. The water temperature is lowered until the Fahrenheit temperature observed is $140°F$. At that time the temperature registered by the centigrade thermometer is

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Options:

A. $80^\circ\mathrm{C}$

B. $60^\circ\mathrm{C}$

C. $40^\circ\mathrm{C}$

D. $20^\circ\mathrm{C}$

Answer: B

Solution:

The relation between Celsius (centigrade, C) and Fahrenheit (F) is:

$F = \frac{9}{5}C + 32$

Given:

$F = 140^\circ\mathrm{F}$

Let the temperature registered by the centigrade thermometer be $C^\circ\mathrm{C}$.

Substitute the value of F:

$140 = \frac{9}{5}C + 32$

Subtract 32 from both sides:

$140 - 32 = \frac{9}{5}C$

$108 = \frac{9}{5}C$

Multiply both sides by 5:

$540 = 9C$

Divide both sides by 9:

$C = \frac{540}{9} = 60$

So, the temperature on the centigrade thermometer will be $60^\circ\mathrm{C}$.

Answer:

Option B $60^\circ\mathrm{C}$

Question65

An engine operating between temperatures T_1 and T_2 has efficiency $\frac{1}{5}$. When T_2 is lowered by 45 K , its efficiency becomes $\frac{1}{2}$. Temperatures T_1 and T_2 are respectively

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Options:

A. 100 K, 70 K

B. 160 K, 120 K

C. 140 K, 110 K

D. 150 K, 120 K

Answer: D

Solution:

Let T_1 be the higher temperature and T_2 be the lower temperature.

For a Carnot engine, efficiency η is given by:

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

Step 1: Using first condition ($\eta = \frac{1}{5}$)

$1 - \frac{T_2}{T_1} = \frac{1}{5}$

$\frac{T_2}{T_1} = 1 - \frac{1}{5} = \frac{4}{5}$

$T_2 = \frac{4}{5} T_1$

Step 2: Second condition (T_2 decreased by $45\ K$, efficiency $\frac{1}{2}$)

New lower temperature $T_2' = T_2 - 45$.

$\eta' = 1 - \frac{T_2 - 45}{T_1} = \frac{1}{2}$

$1 - \frac{T_2 - 45}{T_1} = \frac{1}{2}$

$\frac{T_2 - 45}{T_1} = 1 - \frac{1}{2} = \frac{1}{2}$

$T_2 - 45 = \frac{1}{2}T_1$

Step 3: Solving the two equations

From above:

- $T_2 = \frac{4}{5}T_1$
- $T_2 - 45 = \frac{1}{2}T_1$

Substituting T_2 from first into second:

$\frac{4}{5}T_1 - 45 = \frac{1}{2}T_1$

$\frac{4}{5}T_1 - \frac{1}{2}T_1 = 45$

Take common denominator:

$\frac{8-5}{10}T_1 = 45$

$\frac{3}{10}T_1 = 45$

$T_1 = 45 \times \frac{10}{3} = 150\ K$

$T_2 = \frac{4}{5} \times 150 = 120\ K$

Step 4: Final answer

$\boxed{T_1 = 150\ K, \quad T_2 = 120\ K}$

Answer: Option D

Question66

Two cylinders A and B fitted with pistons contain equal amount of an ideal rigid diatomic gas at 303 K . The piston of cylinder A is free to move and that of cylinder B is held fixed. The same amount heat is given to the gas in each cylinder. If the rise in temperature of the gas in cylinder B is 49 K , then the rise in temperature of the gas in A is

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Options:

A. 30 K

B. 35 K

C. 70 K

D. 75 K

Answer: B

Solution:

Given:

- Two cylinders, both contain equal amount of an ideal rigid diatomic gas at 303 K.
- Cylinder A: Piston is free (constant pressure process).
- Cylinder B: Piston is fixed (constant volume process).
- Equal amount of heat Q is supplied to both.
- In cylinder B (constant volume), the rise in temperature is 49 K.
- Find the rise in temperature of gas in A (constant pressure).

Step 1: Molar heat capacities

For a **rigid diatomic gas** (rotation possible, vibration neglected):

- Degrees of freedom = 5
- $C_V = \frac{5}{2}R$
- $C_P = C_V + R = \frac{7}{2}R$

Step 2: Heat supplied in each process

Let n be the number of moles.

Cylinder B (Constant volume):

$Q = nC_V\Delta T_B$

Given $\Delta T_B = 49\,\text{K}$,

$Q = n\left(\frac{5}{2}R\right) \times 49$

Cylinder A (Constant pressure):

$Q = nC_P\Delta T_A$

But same Q as above, so:

$nC_P\Delta T_A = nC_V\Delta T_B$

Substitute $C_P = \frac{7}{2}R$, $C_V = \frac{5}{2}R$,

$n\left(\frac{7}{2}R\right)\Delta T_A = n\left(\frac{5}{2}R\right) \times 49$

Cancel n and $\frac{1}{2}R$ from both sides:

$7\Delta T_A = 5 \times 49$

$\Delta T_A = \frac{5\times49}{7} = \frac{245}{7} = 35\,\mathrm{K}$

Final Answer:

Option B: $35\,\mathrm{K}$

Question67

If a gas is compressed isothermally then the r.m.s. velocity of its molecules

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Options:

A. increases.

B. decreases.

C. remains the same.

D. first increases and then decreases.

Answer: C

Solution:

If a gas is compressed **isothermally**, its temperature remains constant.

The root mean square (r.m.s.) velocity of gas molecules is given by:

$v_{rms} = \sqrt{\frac{3kT}{m}}$

where:

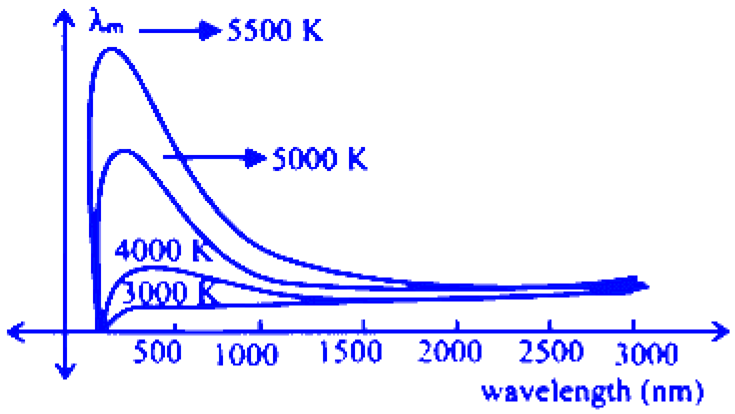
- k = Boltzmann constant,
- T = absolute temperature,
- m = mass of one molecule.

Since the r.m.s. velocity depends only on temperature T, and **isothermal** means temperature does not change, the r.m.s. velocity **remains the same**.

Correct answer: Option C - remains the same.

Question68

The following graph represents the radiant power versus wavelength of the black body. The area under the curve represents



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Options:

A. the maximum wavelength emitted by the object.

B. the minimum wavelength emitted by the object.

C. the total energy emitted per unit time by the black body at some particular wavelength

D. the total energy emitted per unit time per unit area by the black body at all wavelengths.

Answer: D

Solution:

Answer: (d) the total energy emitted per unit time per unit area by the black body at all wavelengths.

The area under a black-body radiation curve (which plots radiant power per unit area versus wavelength) represents the total energy emitted per unit time per unit area by the black body across all wavelengths. This total emissive power is directly related to the fourth power of the black body's absolute temperature (T^4), as described by the Stefan-Boltzmann law.

Question69

In a cyclic process, work done by the system is

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Options:

A. more than the heat given to the system.

B. equal to the heat given to the system.

C. zero.

D. independent of the heat given to the system.

Answer: B

Solution:

In a cyclic process, the system returns to its initial state. According to the first law of thermodynamics,

$$\Delta U = Q - W$$

where ΔU is the change in internal energy, Q is the heat given to the system, and W is the work done by the system.

For a cyclic process:

- The system returns to its original state, so $\Delta U = 0$.

So,

$$0 = Q - W \implies Q = W$$

Correct answer:

Option B: equal to the heat given to the system.

Question70

A metal sphere cools at a rate of $1.5^{\circ}\mathrm{C}/\mathrm{min}$ when its temperature is $80^{\circ}\mathrm{C}$. When the temperature of the sphere is $40^{\circ}\mathrm{C}$, its rate of

cooling is $0.3^{\circ}\mathrm{C}/\mathrm{min}$. The temperature of the surrounding (θ_0) is

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Options:

A. $30^{\circ}\mathrm{C}$

B. $35^{\circ}\mathrm{C}$

C. $25^{\circ}\mathrm{C}$

D. $27^{\circ}\mathrm{C}$

Answer: A

Solution:

According to Newton's law of cooling,

$\left|\frac{\mathrm{dT}}{\mathrm{dt}}\right| = \mathrm{k}\left(\mathrm{T}-\theta_0\right)$

At $\mathrm{T}=80^{\circ}, 1.5=\mathrm{k}\left[80-\theta_0\right]$

At $\mathrm{T}=40^{\circ}, 0.3=\mathrm{k}\left[40-\theta_0\right]$

Dividing (i) and (ii)

$$\frac{1.5}{0.3}=\frac{80-\theta_0}{40-\theta_0}$$

$\Rightarrow 200-5\theta_0=80-\theta_0$
$\Rightarrow 4\theta_0=120$
$\Rightarrow \theta_0=30^{\circ}\mathrm{C}$

Question71

The change in the internal energy of the mass of gas, when the volume changes from V to 2 V at constant pressure P is $\left(\gamma=\frac{\mathrm{Cp}}{\mathrm{Cv}}\right)$

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Options:

A. $\frac{V}{P(\gamma-1)}$

B. $\frac{P}{V(\gamma-1)}$

C. $\frac{PV}{\gamma+1}$

D. $\frac{PV}{\gamma-1}$

Answer: D

Solution:

Change in internal energy is given by,

$\Delta U = nC_v\Delta T \qquad \ldots(i)$

Given, $\frac{C_P}{C_v} = \gamma$ and $C_P - C_v = R$

$$1 + \frac{R}{C_V} = \gamma$$
$$C_V = \frac{R}{(\gamma - 1)}$$
$$\therefore \Delta U = n\left(\frac{R}{\gamma - 1}\right)\Delta T \quad \ldots[From(i)]$$

Using $P\Delta V = nR\Delta T$ under constant P,

$$\Delta U = \frac{P\Delta V}{\gamma - 1} = \frac{P(2V - V)}{\gamma - 1} = \frac{PV}{(\gamma - 1)}$$

Question72

For a perfectly black body, coefficient of emission is

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Options:

A. zero.

B. unity.

C. less than one (non-zero).

D. infinity.

Answer: B

Solution:

For a perfectly black body:

- **By definition**, a black body absorbs all the radiation incident on it.
- According to Kirchhoff's law of radiation, **for a body in thermal equilibrium, the ratio of emissive power to absorptive power is the same for all bodies at a given temperature and wavelength**.
- Since a black body has **absorptivity = 1**, it also has **emissivity = 1**.

Therefore,

Correct option: B. unity ✅

Question73

A body cools from $60^{\circ} \mathrm{C}$ to $40^{\circ} \mathrm{C}$ in 6 minutes. After next 6 minutes its temperature will be (Temperature of the surroundings is $10^{\circ} \mathrm{C}$)

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Options:

A. $24^{\circ} \mathrm{C}$

B. $28^{\circ} \mathrm{C}$

C. $18^{\circ} \mathrm{C}$

D. $32^{\circ} \mathrm{C}$

Answer: B

Solution:

According to Newton's law of cooling,

$\frac{\theta_1-\theta_2}{\mathrm{t}}=\mathrm{K}\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

where, $\theta_0=$ temperature of surrounding

$$\therefore \quad \frac{60-40}{6}=K\left[\frac{60+40}{2}-10\right]$$
$$\frac{20}{6}=K \times 40 \quad \ldots(i)$$
$$K=\frac{1}{12}$$

After another t min , let the temperature be x .

$\therefore \quad \frac{40-x}{6}=\frac{1}{12}\left[\frac{40+x}{2}-10\right]$ ...[using (i)]

$\therefore \quad 40-x=\frac{20+x}{4}$

$\therefore \quad 160-4x=20+x$

$\therefore \quad 5x=140$

$\therefore \quad x=\frac{140}{5}=28^{\circ}\mathrm{C}$

Question74

A tyre of a vehicle is filled with air having pressure 270 kPa at $27^{\circ}\mathrm{C}$. The air pressure in the tyre when the temperature increases to $37^{\circ}\mathrm{C}$ is

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Options:

A. 282 kPa

B. 270 kPa

C. 265 kPa

D. 279 kPa

Answer: D

Solution:

We use **Gay-Lussac's Law** (Pressure Law) for this question. According to this law, for a fixed amount of gas at constant volume:

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

where,

- $P_1 = 270$ kPa
- $T_1 = 27^\circ\text{C} = 27 + 273 = 300$ K
- $T_2 = 37^\circ\text{C} = 37 + 273 = 310$ K
- $P_2 = ?$ (final pressure)

Let's substitute the values:

$\frac{270}{300} = \frac{P_2}{310}$

Now solve for P_2:

$P_2 = \frac{270 \times 310}{300}$

$P_2 = \frac{83700}{300} = 279$ kPa

Final Answer:

Option D: 279 kPa

Question75

The average force applied on the walls of a closed container depends as T^x where T is the temperature of an ideal gas. The value of x is

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Options:

A. 1

B. 2

C. 3

D. 4

Answer: A

Solution:

Let us solve the problem step by step.

1. **Pressure of an Ideal Gas:**

   According to the kinetic theory of gases, the pressure (P) exerted by an ideal gas is given by:

   $P = \frac{1}{3}\frac{Nm\langle v^2\rangle}{V}$

   where

   N = number of molecules,

   m = mass of one molecule,

   $\langle v^2\rangle$ = mean square speed,

   V = volume.

2. **Kinetic Energy and Temperature:**

   The average kinetic energy of one molecule is

   $\frac{1}{2}m\langle v^2\rangle = \frac{3}{2}k_BT$

   Thus,

   $m\langle v^2\rangle = 3k_BT$

3. **Expressing Pressure in Terms of Temperature:**

   Substitute the value from step 2 into the pressure equation:

   $P = \frac{1}{3}\cdot\frac{N}{V}\cdot(3k_BT)$

   $P = \frac{N}{V}k_BT$

   For a fixed number of molecules and volume, N and V are constant.

4. **Force on the Walls:**

   Pressure (P) is force (F) per unit area (A). So,

   $P = \frac{F}{A} \implies F = P \cdot A$

   For a given container (fixed area), $F \propto P$.

5. **Dependence on Temperature:**

   From above, $P \propto T$

   So, $F \propto T$

6. **Value of x:**

   Force on walls $\propto T^x$,

   So, $x = 1$.

Final Answer:

Option A

$\boxed{1}$

Question76

A diatomic gas $\left(\gamma = \frac{7}{5}\right)$ is compressed adiabatically to volume $\frac{\mathrm{V}_0}{32}$, where V_0 is its initial volume. The initial temperature of the gas is T_i in kelvin and the final temperature is xT_i in kelvin. The value of x is

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Options:

A. 5

B. 4

C. 3

D. 2

Answer: B

Solution:

For an adiabatic process:

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

Let the initial state be (T_i, V_0) and the final state be (T_f, V_f).

Given:

- $\gamma = \frac{7}{5}$
- $V_f = \frac{V_0}{32}$
- $T_f = xT_i$

We can write:

$T_i V_0^{\gamma-1} = T_f V_f^{\gamma-1}$

Substitute the values:

$T_i V_0^{\gamma-1} = x T_i \left(\frac{V_0}{32}\right)^{\gamma-1}$

Divide both sides by T_i:

$V_0^{\gamma-1} = x \left(\frac{V_0}{32}\right)^{\gamma-1}$

Rewrite the right side:

$= x \cdot V_0^{\gamma-1} \cdot 32^{-(\gamma-1)}$

Now, cancel $V_0^{\gamma-1}$ from both sides:

$1 = x \cdot 32^{-(\gamma-1)}$

Bring $32^{\gamma-1}$ to the left:

$x = 32^{\gamma-1}$

Now, calculate $\gamma - 1$:

$\gamma - 1 = \frac{7}{5} - 1 = \frac{2}{5}$

Now:

$x = 32^{2/5}$

Recall, $32 = 2^5$:

$32^{2/5} = (2^5)^{2/5} = 2^2 = 4$

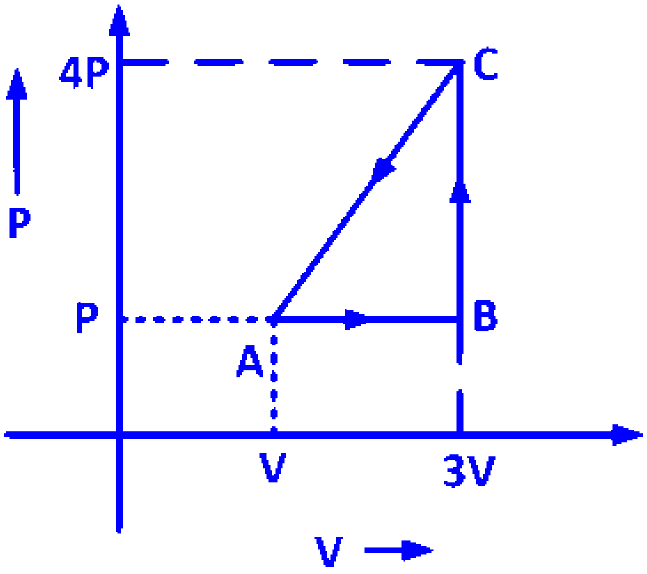
So,

$x = 4$

Correct Option: B (4)

Question77

The work done by a gas as it is taken in a cyclic process (shown in graph) is



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Options:

A. 2 pv

B. -2 pv

C. 3 pv

D. -3 pv

Answer: D

Solution:

Work done is given by area of $\triangle ABC$

$-\frac{1}{2} \times (3-1)\mathrm{v} \times (4-1)\mathrm{p} = -\frac{6}{2}\mathrm{pv} = -3\mathrm{pv}$

Question78

Two gases A and B are at absolute temperatures 350 K and 420 K respectively. The ratio of average kinetic energy of the molecules of gas B to that of gas A is

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Options:

A. 6 : 5

B. $\sqrt{6} : \sqrt{5}$

C. 36 : 25

D. 5 : 6

Answer: A

Solution:

The average kinetic energy of a gas molecule is given by:

Average kinetic energy $= \frac{3}{2}kT$

where k is the Boltzmann constant and T is the absolute temperature.

Let $T_A = 350\,\text{K}$ (for gas A) and $T_B = 420\,\text{K}$ (for gas B).

The ratio of average kinetic energies:

$$\frac{\text{Average KE of B}}{\text{Average KE of A}} = \frac{\frac{3}{2}kT_B}{\frac{3}{2}kT_A} = \frac{T_B}{T_A}$$

Substitute the values:

$$\frac{T_B}{T_A} = \frac{420}{350} = \frac{42}{35} = \frac{6}{5}$$

Therefore, the ratio is $6:5$.

Correct answer: Option A

Question79

A composite slab consists of two materials having coefficients of thermal conductivity K and $2K$, thickness x and $4x$ respectively. The temperatures of two outer surfaces of a composite slab are T_2 and T_1 respectively $(T_2 > T_1)$. The rate of heat transfer through the slab in a steady state is $\left[\frac{A(T_2-T_1)K}{x}\right]f$, where f is equal to

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Options:

A. 1

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

C. $\frac{1}{2}$

D. $\frac{1}{3}$

Answer: D

Solution:

Let the two slabs have:

- **Slab 1:** Thermal conductivity K, thickness x
- **Slab 2:** Thermal conductivity $2K$, thickness $4x$

Let the temperature at the interface be T.

Step 1: Write heat transfer equations for each slab

For steady-state, the **rate of heat transfer (Q) through each layer is same**:

For **Slab 1**:

$$Q = \frac{K\,A\,(T_2 - T)}{x}$$

For **Slab 2**:

$$Q = \frac{2K\,A\,(T - T_1)}{4x}$$

Step 2: Equate the rates and solve for T

Set the two Q values equal:

$$\frac{K\,A\,(T_2 - T)}{x} = \frac{2K\,A\,(T - T_1)}{4x}$$

Simplify:

- K and A cancel out.
- $2/(4x) = 1/(2x)$:

$$\frac{T_2 - T}{x} = \frac{T - T_1}{2x}$$

Cross-multiplied:

$2(T_2 - T) = T - T_1$

$2T_2 - 2T = T - T_1$

$2T_2 + T_1 = 3T$

$T = \frac{2T_2+T_1}{3}$

Step 3: Substitute T back to find Q in terms of T_2 and T_1

Recall:

$Q = \frac{K\,A\,(T_2-T)}{x}$

Use $T = \dfrac{2T_2 + T_1}{3}$:

$T_2 - T = T_2 - \frac{2T_2+T_1}{3} = \frac{3T_2-2T_2-T_1}{3} = \frac{T_2-T_1}{3}$

So,

$Q = \frac{K\,A}{x} \cdot \frac{T_2-T_1}{3}$

Or,

$Q = \left[\frac{A(T_2-T_1)K}{x}\right] \cdot \frac{1}{3}$

Step 4: Compare with the question's expression

Here,

$f = \frac{1}{3}$

Final Answer:

Option D: $f = \dfrac{1}{3}$

Question80

The co-efficient of absorption and the coefficient of reflection of a thin uniform plate are 0.77 and 0.17 respectively. If 250 kcal of heat is incident on the surface of the plate, the quantity of heat transmitted is

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Options:

A. 7 kcal

B. 12 kcal

C. 15 kcal

D. 22 kcal

Answer: C

Solution:

Given:

- Coefficient of absorption, $a = 0.77$
- Coefficient of reflection, $r = 0.17$
- Incident heat, $Q = 250$ kcal

We know that:

$a + r + t = 1$

where t is the coefficient of transmission.

Step 1: Find the coefficient of transmission

$t = 1 - (a + r)$

$t = 1 - (0.77 + 0.17)$

$t = 1 - 0.94$

$t = 0.06$

Step 2: Find the heat transmitted

Transmitted heat $= t \times Q$

Transmitted heat $= 0.06 \times 250$

Transmitted heat $= 15$ kcal

Final Answer:

Option C: 15 kcal

Question81

An ideal gas at pressure ' P ' and temperature ' T ' is enclosed in a vessel of volume ' V '. Some gas leaks through a hole from the vessel

and the pressure of the enclosed gas falls to ' P '. Assuming that the temperature ture of the gas remains constant during the leakage , the number of moles of the gas that have leaked is

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Options:

A. $\frac{2\text{ V}}{\text{RT}}(\text{P}-\text{P}')$

B. $\frac{\text{V}}{\text{RT}}(\text{P}-\text{P}')$

C. $\frac{\text{V}}{\text{RT}}(\text{P}+\text{P}')$

D. $\frac{\text{V}}{2\text{RT}}(\text{P}+\text{P}')$

Answer: B

Solution:

Given:

- Initial pressure of gas = P
- Final pressure of gas after leakage = P'
- Volume = V (constant)
- Temperature = T (constant)

We need to find **the number of moles of gas that have leaked**.

Step 1: Write the ideal gas law

$PV = nRT$

Where:

- P = Pressure
- V = Volume
- n = Number of moles
- R = Universal gas constant
- T = Temperature

Step 2: Calculate initial number of moles, n_1

$n_1 = \frac{PV}{RT}$

Step 3: Calculate final number of moles, n_2 (after leakage)

$n_2 = \frac{P'V}{RT}$

Step 4: Number of moles leaked

Number of moles leaked $= n_1 - n_2 = \frac{PV}{RT} - \frac{P'V}{RT}$

$= \frac{V}{RT}(P - P')$

Step 5: Match with the given options

The correct option is:

$$\boxed{\frac{V}{RT}(P - P')}$$

So, the correct answer is Option B.

Question82

If r.m.s. velocity of hydrogen molecules is 4 times that of an oxygen molecule at 47°C, the temperature of hydrogen molecules is (Molecular weight of Hydrogen and Oxygen are 2 and 32 respectively)

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Options:

A. 23°C

B. 47°C

C. 80°C

D. 114°C

Answer: B

Solution:

Given:

- r.m.s. velocity of hydrogen $= 4\times$ r.m.s. velocity of oxygen
- Temperature of oxygen, $T_{O_2} = 47^\circ C = 320$ K
- Molecular mass of Hydrogen, $M_{H_2} = 2$
- Molecular mass of Oxygen, $M_{O_2} = 32$

Step 1: Formula for r.m.s. velocity

The r.m.s. velocity of a gas molecule is:

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

where

$R =$ universal gas constant

$T =$ absolute temperature (in K)

$M =$ molar mass (in kg/mol or g/mol as long as units are consistent)

Step 2: Ratio of r.m.s. velocities

Let temperature of hydrogen be T_{H_2}.

Given:

$$v_{rms, H_2} = 4\, v_{rms, O_2}$$

From the formula,

$$\frac{v_{rms, H_2}}{v_{rms, O_2}} = \frac{\sqrt{\frac{3RT_{H_2}}{M_{H_2}}}}{\sqrt{\frac{3RT_{O_2}}{M_{O_2}}}}$$

This simplifies to,

$$\frac{v_{rms, H_2}}{v_{rms, O_2}} = \sqrt{\frac{T_{H_2} M_{O_2}}{T_{O_2} M_{H_2}}}$$

Step 3: Substitute given values and solve for T_{H_2}

Given, $\frac{v_{rms, H_2}}{v_{rms, O_2}} = 4$

So,

$$4 = \sqrt{\frac{T_{H_2}\times 32}{320\times 2}}$$

Now, square both sides:

$$16 = \frac{T_{H_2}\times 32}{320\times 2}$$

$$16 = \frac{32T_{H_2}}{640}$$

$$16 = \frac{T_{H_2}}{20}$$

So,

$T_{H_2} = 16 \times 20 = 320 \text{ K}$

Step 4: Convert to degree Celsius

$T(^\circ\text{C}) = T(\text{K}) - 273$

$T_{H_2} = 320 - 273 = 47^\circ\text{C}$

Final Answer:

$\boxed{47^\circ\text{C}}$ (Option B)

Question83

A monoatomic ideal gas is heated at constant pressure. The percentage of total heat used in increasing the internal energy and that used for doing external work is A and B respectively. Then the ratio, A : B is

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Options:

A. 5 : 3

B. 2 : 3

C. 3 : 2

D. 2 : 5

Answer: C

Solution:

Let us solve step by step:

Step 1: Total Heat Supplied at Constant Pressure

For n moles of an ideal gas heated at constant pressure,

- Heat supplied: $Q = nC_p\Delta T$

  Where C_p is molar specific heat at constant pressure.

For a **monoatomic ideal gas**:

- $C_v = \frac{3}{2}R$
- $C_p = C_v + R = \frac{5}{2}R$

So,

$$Q = nC_p\Delta T = n\left(\frac{5}{2}R\right)\Delta T$$

Step 2: Increase in Internal Energy (ΔU)

For n moles,

$$\Delta U = nC_v\Delta T = n\left(\frac{3}{2}R\right)\Delta T$$

Step 3: Work Done by the Gas (W) **at Constant Pressure**

$$W = P\Delta V = nR\Delta T$$

Step 4: Find Percentage of Heat Used for ΔU **and** W

Fraction for ΔU:

$$\frac{\Delta U}{Q} = \frac{n\cdot\frac{3}{2}R\Delta T}{n\cdot\frac{5}{2}R\Delta T} = \frac{3}{5}$$

So, percentage is 60%.

Fraction for W:

$$\frac{W}{Q} = \frac{nR\Delta T}{n\cdot\frac{5}{2}R\Delta T} = \frac{2}{5}$$

So, percentage is 40%.

Step 5: Ratio A : B

A : B $= 60\% : 40\% = 3 : 2$

Final Answer:

Option C: 3 : 2

Question84

Black sphere of radius R radiates power P at certain temperature T. If the temperature is doubled, the radius gets doubled. Now the power radiated would be

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Options:

A. 4 P

B. 8 P

C. 16 P

D. 64 P

Answer: D

Solution:

Let the initial radius be R and initial temperature be T.

Step 1: Write the formula for power radiated by a black body

According to Stefan-Boltzmann law,

$P = \sigma \cdot A \cdot T^4$

where σ is the Stefan-Boltzmann constant, A is the surface area, and T is the temperature.

For a sphere, $A = 4\pi R^2$.

So,

$P = \sigma \cdot 4\pi R^2 T^4$

Step 2: Write the expression for the new power

When temperature is doubled $(2T)$ and radius is also doubled $(2R)$:

Let the new power be P',

$P' = \sigma \cdot 4\pi (2R)^2 (2T)^4$

Step 3: Expand $(2R)^2$ and $(2T)^4$

$(2R)^2 = 4R^2$

$(2T)^4 = 16T^4$

So,

$P' = \sigma \cdot 4\pi \cdot 4R^2 \cdot 16T^4$

Step 4: Multiply and simplify

$P' = \sigma \cdot 4\pi \cdot 4 \cdot 16 \cdot R^2 T^4$

$P' = \sigma \cdot 4\pi \cdot 64 \cdot R^2 T^4$

But the original power $P = \sigma \cdot 4\pi R^2 T^4$

So,

$P' = 64 \cdot P$

Final Answer:

$\boxed{64P}$

So, **Option D** is correct.

Question85

Three samples X, Y, and Z of same gas have equal volumes and temperatures. The volume of each sample is doubled, the process being isothermal for X , adiabatic for Y and isobaric for Z . If the final pressures are equal for the three samples, the ratio of the initial pressures is ($\gamma = 3$ / 2)

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Options:

A. $1 : \sqrt{2} : 2\sqrt{3}$

B. $2 : 2\sqrt{2} : 1$

C. $3 : 3\sqrt{3} : 1$

D. $5 : 5\sqrt{5} : 1$

Answer: B

Solution:

Given:

- Three samples of a gas (X, Y, Z) have equal initial volumes (V) and temperatures.
- Volume is doubled for each sample $(V \to 2V)$ by different processes:
- X: Isothermal
- Y: Adiabatic $(\gamma = \frac{3}{2})$
- Z: Isobaric

Let the initial pressures be P_X, P_Y, P_Z.

Let the final pressures (after the process) for all be P (equal for all).

We have to find $P_X : P_Y : P_Z$.

Step 1: Isothermal Process (Sample X)

For isothermal process:

$P_X V = P \cdot 2V$

Solve for P_X:

$P_X = 2P$

Step 2: Adiabatic Process (Sample Y)

For adiabatic:

$P_Y V^\gamma = P(2V)^\gamma$

Plug in $\gamma = \frac{3}{2}$:

$P_Y V^{3/2} = P \cdot (2V)^{3/2}$

$P_Y = P \cdot \frac{(2)^{3/2}}{1}$

$P_Y = P \cdot 2^{3/2}$

$2^{3/2} = (\sqrt{2})^3 = 2\sqrt{2}$

$P_Y = 2\sqrt{2}\,P$

Step 3: Isobaric Process (Sample Z)

For isobaric, pressure is constant during the process, so:

$P_Z = P$

Step 4: Ratio

$P_X : P_Y : P_Z = 2P : 2\sqrt{2}\,P : P$

$= 2 : 2\sqrt{2} : 1$

Answer:

Option B $\boxed{2 : 2\sqrt{2} : 1}$

Question86

Two rods of different materials have lengths ' l ' and ' l_2 ' whose coefficient of linear expansions are ' α_1 ' and ' α_2 ' respectively. If the difference between the two lengths is independent of temperature then

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Options:

A. $\alpha_1^2 l_1 = \alpha_2^2 l_2$

B. $\frac{l_1}{l_2} = \frac{\alpha_2}{\alpha_1}$

C. $\frac{l_1}{l_2} = \frac{\alpha_1}{\alpha_2}$

D. $l_1^2 \alpha_2 = l_2^2 \alpha_1$

Answer: B

Solution:

Let the original lengths of the rods be l_1 and l_2.

Let the coefficients of linear expansion be α_1 and α_2.

Step 1 (Write the expansion formula):

When temperature increases by ΔT, the new lengths are:

- First rod: $l_1' = l_1(1 + \alpha_1 \Delta T)$
- Second rod: $l_2' = l_2(1 + \alpha_2 \Delta T)$

Step 2 (Find the difference in lengths):

Difference after expansion:

Difference $= l_1'(T) - l_2'(T) = l_1(1 + \alpha_1 \Delta T) - l_2(1 + \alpha_2 \Delta T)$

Simplify:

$= (l_1 - l_2) + (l_1 \alpha_1 - l_2 \alpha_2) \Delta T$

Step 3 (Condition given in the question):

The difference should be **independent of temperature**.

So coefficient of ΔT must be zero:

$l_1 \alpha_1 - l_2 \alpha_2 = 0$

$l_1 \alpha_1 = l_2 \alpha_2$

$\frac{l_1}{l_2} = \frac{\alpha_2}{\alpha_1}$

Step 4 (Choose the correct option):

This matches **Option B**.

Final Answer:

$$\boxed{\frac{l_1}{l_2}=\frac{\alpha_2}{\alpha_1}}$$

So, the correct answer is **Option B**.

Question87

The molar specific heat of an ideal gas at constant pressure and constant volume is ' $\mathrm{C_p}$ ' and ' $\mathrm{C_v}$ ' respectively. If ' R ' is a universal gas constant and the ratio of ' $\mathrm{C_p}$ ' to ' $\mathrm{C_v}$ ' is γ, then ' $\mathrm{C_p}$ ' is equal to

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Options:

A. $\left(\frac{\gamma-1}{\gamma+1}\right)\mathrm{R}$

B. $\frac{(\gamma-1)R}{\gamma}$

C. $\frac{\mathrm{R}\gamma}{(\gamma-1)}$

D. $\frac{\mathrm{R}\gamma}{(\gamma+1)}$

Answer: C

Solution:

Given:

- Molar specific heat at constant pressure $= C_p$
- Molar specific heat at constant volume $= C_v$
- Universal gas constant $= R$
- Ratio $\gamma = \dfrac{C_p}{C_v}$

Standard Relations:

1. **Relation between C_p, C_v and R:**

   $C_p - C_v = R$

2. **Given:**

$\gamma = \frac{C_p}{C_v}$

Step 1: Express C_p in terms of C_v:

$C_p = \gamma C_v$

Step 2: Substitute C_p in the first equation:

$C_p - C_v = R \Rightarrow (\gamma C_v) - C_v = R \Rightarrow (\gamma - 1)C_v = R$

Step 3: Express C_v:

$C_v = \frac{R}{\gamma - 1}$

Step 4: Express C_p in terms of R and γ:

Recall, $C_p = \gamma C_v$, so:

$C_p = \gamma \cdot \frac{R}{\gamma - 1} = \frac{\gamma R}{\gamma - 1}$

Final Answer:

The correct expression is:

$C_p = \frac{\gamma R}{\gamma - 1}$

Option C is correct.

Question88

For ideal non-rigid diatomic gas, the value of $\frac{R}{C_V}$ is nearly $\left(\gamma = \frac{C_P}{C_V} = \frac{9}{7}\right)$

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Options:

A. 0.4

B. 0.66

C. 0.28

D. 1.28

Answer: C

Solution:

Given:

For an ideal non-rigid diatomic gas, $\gamma = \dfrac{C_P}{C_V} = \dfrac{9}{7}$

We are to find the value of $\dfrac{R}{C_V}$.

Step 1: Formula for γ

$\gamma = \frac{C_P}{C_V}$

Step 2: Relation between C_P, C_V, and R

$C_P - C_V = R \implies C_P = C_V + R$

Step 3: Plug this value into the formula for γ

$\gamma = \frac{C_V + R}{C_V}$

$\gamma = 1 + \frac{R}{C_V}$

Step 4: Rearranging to find $\frac{R}{C_V}$

$\gamma = 1 + \frac{R}{C_V}$

$\gamma - 1 = \frac{R}{C_V}$

Step 5: Substitute the value of γ

$\gamma = \frac{9}{7}$

$\gamma - 1 = \frac{9}{7} - 1 = \frac{9-7}{7} = \frac{2}{7}$

Therefore,

$$\boxed{\frac{R}{C_V} = \frac{2}{7} \approx 0.28}$$

So, the correct option is

Option C: 0.28

Question89

When the heat is given to a gas in an Isothermal process, then there will be

Options:

A. external work done.

B. rise in temperature.

C. increase in internal energy.

D. external work done and also rise in temperature.

Answer: A

Solution:

In an **isothermal process**, the temperature of the gas **remains constant**.

- By definition, $\Delta T = 0$ (no change in temperature).

According to the first law of thermodynamics:

$\Delta Q = \Delta U + W$

Where:

- ΔQ = Heat supplied to the system
- ΔU = Change in internal energy
- W = Work done by the system

In an isothermal process for an ideal gas:

- $\Delta U = 0$ (since internal energy depends only on temperature, and temperature is constant)
- So, all the heat supplied (ΔQ) is converted into work done (W):

  $\Delta Q = W$

Analysis of Options:

- **Option A:** external work done — Correct, as heat supplied is used to do work.
- **Option B:** rise in temperature — Incorrect, temperature remains constant.
- **Option C:** increase in internal energy — Incorrect, internal energy does not change.
- **Option D:** external work done and also rise in temperature — Incorrect, no rise in temperature.

Final Answer:

Option A: external work done.

Question90

During an experiment, an ideal gas is found to obey an additional law $VP^2 =$ constant. The gas is initially at temperature ' T ' and volume ' V '. What will be the temperature of the gas when it expands to a volume 2 V ?

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Options:

A. $\sqrt{3}$ T

B. $\sqrt{\frac{1}{2T}}$

C. $\sqrt{2}$ T

D. $\sqrt{3 \mathrm{~T}}$

Answer: C

Solution:

To solve this problem, we start by looking at the known relationships for an ideal gas. For an ideal gas, the equation is:

$PV = nRT$

This equation can be rearranged to express pressure P as:

$P = \frac{RT}{V} \quad$ (Equation 1)

The problem states that the gas follows an additional relationship:

$VP^2 =$ constant

Substituting Equation 1 into this relationship, we have:

$V\left(\frac{RT}{V}\right)^2 =$ constant

This simplifies to:

$\frac{R^2T^2}{V} =$ constant

From here, we isolate the temperature term:

$\frac{T^2}{V} = \text{constant}$

Given two states of the gas, the first with volume $V_1 = V$ and temperature $T_1 = T$, and the second after expansion with volume $V_2 = 2V$, we set up the relationship:

$$\left(\frac{T_1}{T_2}\right)^2 = \frac{V_1}{V_2}$$

Substituting the given volumes:

$$\left(\frac{T}{T_2}\right)^2 = \frac{V}{2V}$$

Solving for T_2:

$$\left(\frac{T}{T_2}\right)^2 = \frac{1}{2}$$

Taking the square root:

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

Thus, T_2 is:

$$T_2 = \sqrt{2}T$$

Therefore, when the gas expands to double its initial volume, its temperature will be $\sqrt{2}T$.

Question91

The first operation involved in a Carnot cycle is

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Options:

A. isothermal expansion.

B. adiabatic expansion.

C. isothermal compression.

D. adiabatic compression.

Answer: A

Solution:

The Carnot cycle is composed of four reversible processes:

Isothermal Expansion at the high reservoir temperature, where the system absorbs heat and expands.

Adiabatic Expansion, during which the system continues to expand without heat exchange, and its temperature drops.

Isothermal Compression at the low reservoir temperature, where the system releases heat as it is compressed.

Adiabatic Compression, where the system is compressed without heat exchange, raising its temperature back to the original state.

Since the cycle starts with the process of isothermal expansion, the correct answer is:

Option A: isothermal expansion.

Question92

Temperature remaining constant, the pressure of gas is decreased by 20%. The percentage change in volume

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Options:

A. increases by 29%

B. decreases by 20%

C. increases by 25%

D. decreases by 25%

Answer: C

Solution:

When the temperature is held constant and the pressure of a gas is decreased by 20%, we want to find the percentage change in volume. To solve this, we use the ideal gas law relationship, $P_1V_1 = P_2V_2$.

Given:

The initial pressure (P) is reduced by 20%, resulting in the new pressure (P') being 80% of the original pressure. Therefore, $P' = \frac{80}{100}P$.

By substituting into the equation and solving for the volume change:

$PV = \left(\frac{80}{100}P\right) \cdot V'$

$V' = \frac{100}{80}V$

The percentage increase in volume is calculated by:

Percentage increase in volume $= \left(\frac{V'-V}{V}\right) \times 100$

$= \left(\frac{\frac{100}{80}V-V}{V}\right) \times 100$

$= \left(\frac{\frac{100V-80V}{80}}{V}\right) \times 100$

$= \left(\frac{20}{80}\right) \times 100$

$= \frac{1}{4} \times 100 = 25\%$

Thus, the volume increases by 25%.

Question93

At certain temperature, rod A and rod B of different materials have lengths $\mathrm{L_A}$ and L_B respectively. Their co-efficients of linear expansion are α_A and α_B respectively. It is observed that the difference between their lengths remain constant at all temperatures. The ratio L_A/L_B is given by

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Options:

A. $\frac{\alpha_A}{\alpha_B}$

B. $\frac{\alpha_B}{\alpha_A}$

C. $\frac{\alpha_A+\alpha_B}{\alpha_A}$

D. $\frac{\alpha_A+\alpha_B}{\alpha_B}$

Answer: B

Solution:

Let's analyze the problem step by step:

Assume that at some initial temperature, rod A has length L_A and rod B has length L_B. When the temperature increases by ΔT, the new lengths become:

Rod A: $L_A(1+\alpha_A\Delta T)$

Rod B: $L_B(1+\alpha_B\Delta T)$

The condition given is that the difference between the lengths remains constant at all temperatures. This means:

$L_B(1+\alpha_B\Delta T)-L_A(1+\alpha_A\Delta T)=L_B-L_A$

Expanding the left-hand side:

$L_B+L_B\alpha_B\Delta T-L_A-L_A\alpha_A\Delta T=L_B-L_A$

Notice that the terms L_B and $-L_A$ on both sides cancel, leaving:

$L_B\alpha_B\Delta T-L_A\alpha_A\Delta T=0$

Since $\Delta T\neq 0$, we can divide both sides by ΔT to obtain:

$L_B\alpha_B-L_A\alpha_A=0$

Rearranging the equation gives:

$L_A\alpha_A=L_B\alpha_B$

Finally, dividing both sides by $L_B\alpha_A$ yields:

$\frac{L_A}{L_B}=\frac{\alpha_B}{\alpha_A}$

Thus, the required ratio is:

$\frac{L_A}{L_B}=\frac{\alpha_B}{\alpha_A}$

This corresponds to Option B.

Question94

A monoatomic ideal gas is heated at constant pressure. The percentage of total heat used in changing the internal energy is

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Options:

A. 30%

B. 40%

C. 50%

D. 60%

Answer: D

Solution:

For a monoatomic ideal gas being heated at constant pressure, we need to determine the percentage of the total heat that is used in changing the internal energy.

Given for a monoatomic gas:

$\gamma = \frac{C_p}{C_v} = \frac{5}{3}$

We know the change in heat, ΔQ, is described by:

$\Delta Q = nC_p\Delta T$

And the change in internal energy, ΔU, is given by:

$\Delta U = nC_v\Delta T$

To find the ratio of the change in internal energy to the change in heat supplied, we use:

$\frac{\Delta U}{\Delta Q} = \frac{nC_v\Delta T}{nC_p\Delta T} = \frac{C_v}{C_p} = \frac{3}{5}$

Therefore, the percentage of total heat used in changing the internal energy is:

$\frac{3}{5} \times 100 = 60\%$

Question95

The ratio of the specific heats $\frac{C_p}{C_v} = \gamma$, in terms of degrees of freedom (n) is

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Options:

A. $\left(1 + \frac{1}{n}\right)$

B. $\left(1 + \frac{2}{n}\right)$

C. $\left(1+\frac{n}{3}\right)$

D. $\left(1+\frac{n}{2}\right)$

Answer: B

Solution:

The ratio of the specific heats, denoted as $\frac{C_p}{C_v}=\gamma$, can be expressed in terms of the degrees of freedom (n) of a gas.

We start with the relationship for the specific heat at constant volume, given by:

$C_v=n\times\frac{R}{2}$

Using the relation $C_p-C_v=R$, we can solve for C_p:

$C_p=C_v+R=\frac{nR}{2}+R=\left(\frac{n}{2}+1\right)R$

Now, the ratio of the specific heats γ is:

$\frac{C_p}{C_v}=\frac{\left(\frac{n}{2}+1\right)R}{\frac{nR}{2}}=\left(1+\frac{2}{n}\right)$

Question96

Assuming the expression for the pressure exerted by the gas, it can be shown that pressure is

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Options:

A. $\left(\frac{3}{4}\right)^{\text{th}}$ of kinetic energy per unit volume of a gas.

B. $\left(\frac{2}{3}\right)^{\text{rd}}$ of kinetic energy per unit volume of a gas.

C. $\left(\frac{1}{3}\right)^{\text{rd}}$ of kinetic energy per unit volume of a gas.

D. $\left(\frac{3}{2}\right)^{\text{rd}}$ of kinetic energy per unit volume of a gas.

Answer: B

Solution:

The pressure exerted by a gas on the walls of a container is derived from the kinetic theory of gases. It is represented by the equation:

$P = \frac{1}{3}\rho v^2$

where ρ is the density of the gas, and v is the root mean square (r.m.s.) speed of the gas molecules. We can further express this by noting that density (ρ) is mass (M) per unit volume (V):

$P = \frac{1}{3}\left(\frac{M}{V}\right)v^2$

Next, we multiply and divide the equation by 2, to reframe it in terms of kinetic energy:

$P = \frac{2}{3} \cdot \frac{1}{2}\left(\frac{M}{V}\right)v^2$

Considering that the kinetic energy (K. E.) of the gas per unit volume is given by:

$\text{K. E.} = \frac{1}{2}Mv^2$

The expression for pressure can thus be rewritten as:

$P = \frac{2}{3}\left(\frac{\text{K.E.}}{V}\right)$

This equation shows that the pressure (P) is $\frac{2}{3}$ of the kinetic energy per unit volume of the gas.

Question97

If heat energy ΔQ is supplied to an ideal diatomic gas, the increase in internal energy is ΔU and the amount of work done by the gas is ΔW. The ratio ΔW : ΔU : ΔQ is

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Options:

A. 2 : 3 : 5

B. 2 : 5 : 7

C. 7 : 5 : 9

D. 1 : 2 : 5

Answer: B

Solution:

When heat energy ΔQ is supplied to an ideal diatomic gas, the increase in internal energy is ΔU, and the work done by the gas is ΔW. We need to find the ratio $\Delta W : \Delta U : \Delta Q$.

The fraction of heat energy used to perform external work is determined by the formula:

$$\left(\frac{\Delta W}{\Delta Q}\right) = \left(1 - \frac{1}{\gamma}\right)$$

Here, γ (gamma) for a diatomic gas is $\frac{7}{5}$. Thus, substituting into the formula:

$$\frac{\Delta W}{\Delta Q} = 1 - \frac{1}{\left(\frac{7}{5}\right)} = 1 - \frac{5}{7} = \frac{2}{7} \quad .....(i)$$

Next, the fraction of heat energy used to increase the internal energy is:

$$\frac{\Delta U}{\Delta Q} = \frac{1}{\gamma} = \frac{5}{7} \quad .....(ii)$$

Therefore, combining equations (i) and (ii), the ratios are:

$$\Delta W : \Delta U : \Delta Q = 2 : 5 : 7$$

Question98

The power radiated by a black body is P and it radiates maximum energy around the wavelength λ_0. Now the temperature of the black body is changed so that it radiates maximum energy around wavelength $\left(\frac{\lambda_0}{2}\right)$. The power radiated by it will now increase by a factor of

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Options:

A. 2

B. 8

C. 16

D. 32

Answer: C

Solution:

According to Wien's Law, the product of the wavelength at which a black body radiates maximum energy (λ_m) and its temperature (T) is a constant:

$\lambda_m T = \text{constant}$

If initially the black body radiates maximum energy at wavelength λ_0 and temperature T_1, and then it changes to radiate maximum energy at $\frac{\lambda_0}{2}$, the new temperature T_2 can be found as:

$\lambda_{m_1} T_1 = \lambda_{m_2} T_2$

Substituting the given values:

$T_2 = \frac{\lambda_{m_1}}{\lambda_{m_2}} T_1 = \frac{\lambda_0}{\frac{\lambda_0}{2}} T_1 = 2T_1 \quad \text{... (i)}$

According to the Stefan-Boltzmann Law, the power radiated by a black body is proportional to the fourth power of its temperature:

$P \propto T^4$

For the new power P_2 at temperature T_2, we have:

$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4$

Substituting for T_2 from equation (i):

$\frac{P_2}{P_1} = \left(\frac{2T_1}{T_1}\right)^4 = 16$

Thus, the power radiated by the black body increases by a factor of 16.

Question99

A bucket full of hot water is kept in a room. If it cools from $75^\circ\mathrm{C}$ to $70^\circ\mathrm{C}$ in t_1 minutes, from $70^\circ\mathrm{C}$ to $65^\circ\mathrm{C}$ in t_2 minutes and $65^\circ\mathrm{C}$ to $60^\circ\mathrm{C}$ in t_3 minutes, then

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Options:

A. $\mathrm{t}_1 < \mathrm{t}_2 < \mathrm{t}_3$

B. $t_1 > t_2 > t_3$

C. $t_1 = t_2 = t_3$

D. $t_1 < t_2 = t_3$

Answer: A

Solution:

According to Newton's law of cooling, the rate at which an object cools is proportional to the difference between its average temperature and the ambient temperature.

Thus, the rate of cooling can be expressed as:

Rate of cooling $\propto$ Mean temperature difference

This relationship can be mathematically represented as:

$$\frac{\text{Fall in temperature}}{\text{Time} \quad (t)} \propto \left(\frac{\theta_1+\theta_2}{2} - \theta_0\right)$$

Where:

θ_1 and θ_2 are the initial and final temperatures, respectively.

θ_0 is the ambient room temperature.

Let's evaluate each cooling interval:

Case 1: From 75°C to 70°C

Mean temperature $= \left(\frac{75+70}{2}\right) = 72.5$

Case 2: From 70°C to 65°C

Mean temperature $= \left(\frac{70+65}{2}\right) = 67.5$

Case 3: From 65°C to 60°C

Mean temperature $= \left(\frac{65+60}{2}\right) = 62.5$

From these calculations, we observe:

$72.5 > 67.5 > 62.5$

Since the mean temperature decreases in each subsequent case, the cooling rate is higher initially and decreases over time. This implies:

$t_1 < t_2 < t_3$

Question100

An ideal diatomic gas is heated at constant pressure. What is the fraction of total energy applied, which increases the internal energy for the gas?

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Options:

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

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

C. $\frac{3}{7}$

D. $\frac{3}{5}$

Answer: B

Solution:

To determine the fraction of total energy applied that increases the internal energy of an ideal diatomic gas heated at constant pressure, we use the relationship between heat energy and specific heat capacities. The fraction is given by:

$\frac{\Delta U}{\Delta Q} = \frac{C_v}{C_P} = \frac{1}{\gamma}$

For a diatomic gas, the specific heat ratio γ is $\frac{7}{5}$. Therefore, the fraction of energy used to increase the internal energy is:

$\frac{\Delta U}{\Delta Q} = \frac{5}{7}$

Question101

In ideal gas of $27^{\circ}\mathrm{C}$ is compressed adiabatically to $(8/27)$ of its original volume. If $\gamma = \frac{5}{3}$, the rise in temperature of a gas is

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Options:

A. 300 K

B. 375 K

C. 400 K

D. 450 K

Answer: B

Solution:

For an adiabatic process, the relationship is given by:

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

From this relationship, we can derive the expression for the temperature ratio when a volume change occurs:

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

Given that the initial volume V_1 is reduced to $V_2 = \frac{8}{27}V_1$, and $\gamma = \frac{5}{3}$, the expression becomes:

$\frac{T_2}{T_1} = \left(\frac{27}{8}\right)^{\frac{5}{3}-1} = \left(\frac{27}{8}\right)^{\frac{2}{3}} = \frac{9}{4}$

Now, substituting the initial temperature T_1 (convert the Celsius temperature to Kelvin):

$T_1 = 27 + 273 = 300\,\mathrm{K}$

Calculate T_2:

$T_2 = \frac{9}{4} \times T_1 = \frac{9}{4} \times 300 = 675\,\mathrm{K}$

The rise in temperature is:

$T_2 - T_1 = 675 - 300 = 375\,\mathrm{K}$

Question102

A cylindrical rod is having temperatures θ_1 and θ_2 at its ends. The rate of heat flow is $\mathrm{Q}J/\mathrm{S}$. All the linear dimensions of the rod are doubled by keeping the temperature constant. The new rate of flow of heat is

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Options:

A. 4Q

B. 2Q

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

D. $\frac{Q}{4}$

Answer: B

Solution:

The rate of heat flow through a cylindrical rod can be expressed using the formula:

$$\left(\frac{Q}{t}\right) = \frac{K\pi r^2(\theta_1 - \theta_2)}{\Delta x}$$

In this equation, $\frac{Q}{t}$ represents the rate of heat flow, K is the thermal conductivity, r is the radius of the cylinder, and Δx is the length of the rod. The rate of heat flow is proportional to $\frac{r^2}{\Delta x}$.

When all linear dimensions of the rod are doubled (i.e., both the radius and the length are twice as large), the new dimensions are:

New radius, $r_2 = 2r_1$

New length, $\Delta x_2 = 2\Delta x_1$

The new rate of heat flow, $\frac{Q'}{t}$, is proportional to $\frac{r_2^2}{\Delta x_2}$. Thus, we can write the ratio of the original to the new rate of heat flow as:

$$\frac{Q}{Q'} = \left(\frac{r_1}{r_2}\right)^2 \left(\frac{\Delta x_2}{\Delta x_1}\right) = \left(\frac{1}{2}\right)^2 \times \left(\frac{2}{1}\right) = \frac{1}{2}$$

By rearranging, the new rate of heat flow Q' is:

$$Q' = 2Q$$

Therefore, the new rate of flow of heat is twice the original rate, $2Q$.

Question103

A monoatomic ideal gas, initially at temperature T_1 is enclosed in a cylinder fitted with frictionless piston. The gas is allowed to expand adiabatically to a temperature T_2 by releasing the piston suddenly. L_1 and L_2 are the lengths of the gas columns before and after the expansion respectively. The ratio T_2/T_1 is

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Options:

A. $\left[\frac{\mathrm{L}_1}{\mathrm{L}_2}\right]^{2/3}$

B. $\left[\frac{\mathrm{L}_2}{\mathrm{L}_1}\right]^{2/3}$

C. $\left[\frac{L_2}{L_1}\right]^{1/2}$

D. $\left[\frac{L_1}{L_2}\right]^{1/2}$

Answer: A

Solution:

For an adiabatic process involving an ideal gas, the relationship between initial and final states is given by:

$\mathrm{T}_1\mathrm{V}_1^{\gamma-1} = \mathrm{T}_2\mathrm{V}_2^{\gamma-1}$

From this, the ratio of the final to initial temperatures is:

$\frac{\mathrm{T}_2}{\mathrm{T}_1} = \left(\frac{\mathrm{V}_1}{\mathrm{V}_2}\right)^{\gamma-1}$

For a monoatomic gas, the adiabatic index γ is $\frac{5}{3}$. Thus:

$\gamma - 1 = \frac{5}{3} - 1 = \frac{2}{3}$

The volume of the gas is calculated using the area of the base and the length of the gas column. Thus:

$\mathrm{V}_1 = \mathrm{A}L_1 \quad \text{and} \quad \mathrm{V}_2 = \mathrm{A}L_2$

By substituting these into the expression for $\frac{\mathrm{T}_2}{\mathrm{T}_1}$:

$\frac{\mathrm{T}_2}{\mathrm{T}_1} = \left(\frac{\mathrm{A}L_1}{\mathrm{A}L_2}\right)^{\frac{2}{3}} = \left(\frac{L_1}{L_2}\right)^{\frac{2}{3}}$

Thus, the ratio of the final to initial temperature after adiabatic expansion is:

$\frac{\mathrm{T}_2}{\mathrm{T}_1} = \left(\frac{\mathrm{L}_1}{\mathrm{L}_2}\right)^{\frac{2}{3}}$

Question104

In an ideal gas at temperature T, the average force that a molecule applies on the walls of a closed container depends on T as $\mathrm{T^x}$. The value of x is

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Options:

A. 0.25

B. 2

C. 0.5

D. 1

Answer: D

Solution:

In an ideal gas at temperature T, the average force that a molecule exerts on the walls of a closed container is related to T raised to the power of x. Let's determine the value of x.

The pressure exerted by an ideal gas in a container can be expressed as follows:

$\mathrm{PV} = \mathrm{NK_B}\, T$

Where:

P is the pressure,

V is the volume,

N is the number of molecules,

K_{B} is the Boltzmann constant,

T is the temperature.

Rearranging the formula for force F, we get:

$\frac{F}{A} \cdot V = N K_{\mathrm{B}}\, T$

Here, A is the area on which the force is applied. Solving for F, we find:

$F = \frac{N K_{\mathrm{B}}\, T A}{V}$

From this, it's clear that:

$f \propto T$

Therefore, the exponent x is 1, indicating a direct proportionality between the force and the temperature.

Question105

Heat engine operating between temperature T_1 and T_2 has efficiency $\frac{1}{6}$. When T_2 is lowered by 62 K , its efficiency increases to $\frac{1}{3}$. Then T_1 and T_2 respectively are

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Options:

A. $372 \mathrm{~K}, 310 \mathrm{~K}$

B. $372 \mathrm{~K}, 330 \mathrm{~K}$

C. $330 \mathrm{~K}, 268 \mathrm{~K}$

D. $310 \mathrm{~K}, 248 \mathrm{~K}$

Answer: A

Solution:

Given:

The initial efficiency of the heat engine is $\eta_1 = \frac{1}{6}$, which can be expressed as:

$\eta_1 = 1 - \frac{T_2}{T_1} \quad \Rightarrow \quad T_2 = \frac{5}{6} T_1 \quad$ ...(i)

When the lower temperature T_2 is decreased by 62 K, the efficiency increases to $\eta_2 = \frac{1}{3}$. This can be expressed as:

$\eta_2 = \frac{1}{3} = 1 - \frac{T_2 - 62}{T_1}$

Substituting from equation (i):

$\frac{\left(\frac{5}{6} T_1 - 62\right)}{T_1} = 1 - \frac{1}{3}$

Simplifying this, we get:

$\frac{5}{6}T_1 - 62 = \frac{2}{3}T_1$

Rearranging terms, we find:

$\frac{5}{6}T_1 - \frac{2}{3}T_1 = 62$

Solving this equation will give:

$\frac{1}{6}T_1 = 62$

Thus:

$T_1 = 372\,\mathrm{K}$

Substituting back into equation (i) to find T_2:

$T_2 = \frac{5}{6} \times 372 = 310\,\mathrm{K}$

Thus, the temperatures T_1 and T_2 are 372 K and 310 K, respectively.

Question106

The absolute temperature of a gas is determined by

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Options:

A. the average momentum of the molecule.

B. the velocity of sound in the gas.

C. the number of molecules in the gas.

D. the mean square velocity of the molecules.

Answer: D

Solution:

In the kinetic theory of gases, the absolute temperature T is proportional to the **average (or mean) kinetic energy of the gas molecules**, which in turn is proportional to the **mean square velocity** of the molecules. Symbolically,

$\frac{3}{2}k_BT = \frac{1}{2}m\langle v^2\rangle,$

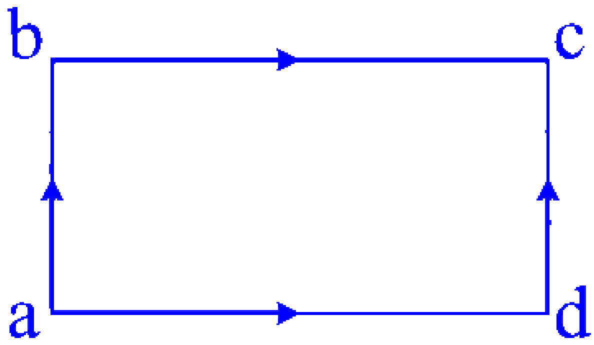
where k_B is Boltzmann's constant, m is the mass of a molecule, and $\langle v^2 \rangle$ is the mean of the square of the molecular speeds.

Therefore, among the given options, the correct statement is that **the absolute temperature of a gas is determined by the mean square velocity of its molecules**.

Answer: (D) the mean square velocity of the molecules.

Question107

When a system is taken from state ' a ' to state ' c ' along a path abc, it is found that $\mathrm{Q}=80\mathrm{cal}$ and $\mathrm{W}=35\mathrm{cal}$. Along path adc $\mathrm{Q}=65\mathrm{cal}$ the work done W along path adc is



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Options:

A. 20 cal.

B. 35 cal.

C. 45 cal.

D. 65 cal.

Answer: A

Solution:

When a system transitions from state 'a' to state 'c', the change in internal energy, denoted as ΔU, remains constant regardless of the path taken.

For the path **abc**, the heat absorbed Q is 80 cal and the work done W is 35 cal. Therefore, the change in internal energy is calculated as:

$\Delta \mathrm{U} = \mathrm{Q} - \mathrm{W} = 80\,\mathrm{cal} - 35\,\mathrm{cal} = 45\,\mathrm{cal}$

For the path **adc**, we know $\Delta U = 45\,\mathrm{cal}$ and the heat absorbed is $\mathrm{Q} = 65\,\mathrm{cal}$.

To find the work done along path adc (W), we use the formula:

$\mathrm{W} = \mathrm{Q} - \Delta \mathrm{U} = 65\,\mathrm{cal} - 45\,\mathrm{cal} = 20\,\mathrm{cal}$

Question108

The ratio of work done by an ideal rigid diatomic gas to the heat supplied by the gas in an isobaric process is

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Options:

A. $\frac{3}{7}$

B. $\frac{2}{7}$

C. $\frac{4}{7}$

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

Answer: B

Solution:

For an isobaric process involving an ideal rigid diatomic gas, the relationship between the heat supplied (ΔQ) and the change in internal energy (ΔU) can be expressed using the specific heat capacities at constant pressure (C_p) and constant volume (C_v):

$\frac{\Delta Q}{\Delta U} = \frac{C_p}{C_v} = \frac{7}{5}$

Using the concept of dividendo, we get:

$\frac{\Delta Q - \Delta U}{\Delta Q} = \frac{7-5}{7} = \frac{2}{7}$

This implies that the ratio of the work done by the gas (W) to the heat supplied (ΔQ) in an isobaric process is:

$\frac{W}{\Delta Q} = \frac{2}{7}$

Question109

The internal energy of an ideal diatomic gas corresponding to volume ' V ' and pressure ' P ' is 2.5 PV. The gas expands from 1 litre to 2 litre at a constant pressure of $10^5 \mathrm{~N} / \mathrm{m}^2$. The heat supplied to a gas is

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Options:

A. 350 J

B. 300 J

C. 250 J

D. 200 J

Answer: A

Solution:

To determine the heat supplied to the ideal diatomic gas, we use the relation:

$Q = \Delta U + W$

Where Q is the heat supplied, ΔU is the change in internal energy, and W is the work done on the system. Given that the internal energy of the gas is $2.5PV$, the work done by the gas during expansion at constant pressure can be expressed as PV.

Thus:

$Q = 2.5PV + PV = 3.5PV$

Substitute the given pressure ($P = 10^5 \mathrm{~N/m}^2$) into the equation:

$Q = 3.5 \times 10^5 = 350 \mathrm{~J}$

Hence, the heat supplied to the gas is 350 J.

Question110

Four moles of hydrogen, two moles of helium and one mole of water vapour form an ideal gas mixture. $[C_{\mathrm{v}}$ for hydrogen $= \frac{5}{2} R, C_v$ for helium $= \frac{3}{2} R, \quad C_{\mathrm{v}}$ for water vapour $= 3\mathrm{R}]$ What is the molar specific heat at constant pressure of the mixture?

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Options:

A. $\frac{11}{3}\mathrm{R}$

B. $\frac{23}{7} R$

C. $\frac{16}{7} R$

D. $\frac{23}{3} R$

Answer: B

Solution:

To find the molar specific heat at constant pressure for the mixture, you can use the formula for molar specific heat at constant pressure, C_p, which is given by:

$C_p = C_v + R$

Using this formula, calculate C_p for each component of the gas mixture:

For hydrogen, the molar specific heat at constant volume is $C_v = \frac{5}{2} R$, so:

$C_{p1} = \frac{5}{2} R + R = \frac{7}{2} R$

For helium, $C_v = \frac{3}{2} R$, so:

$C_{p2} = \frac{3}{2} R + R = \frac{5}{2} R$

For water vapor, $C_v = 3R$, so:

$C_{p3} = 3R + R = 4R$

The number of moles for each gas is given:

$n_1 = 4$ moles of hydrogen

$n_2 = 2$ moles of helium

$n_3 = 1$ mole of water vapor

The total number of moles, n_{total} , is:

$n_{\text{total}} = n_1 + n_2 + n_3 = 4 + 2 + 1 = 7$

Now, calculate the molar specific heat at constant pressure for the mixture using the weighted average of the specific heats:

C_p of mixture $= \frac{n_1 C_{p1} + n_2 C_{p2} + n_3 C_{p3}}{n_{\text{total}}}$

Substitute the values:

C_p of mixture $= \frac{4 \times \frac{7}{2} R + 2 \times \frac{5}{2} R + 1 \times 4R}{7}$

Perform the calculations:

$= \frac{14R + 5R + 4R}{7}$

$= \frac{23R}{7}$

Therefore, the molar specific heat of the mixture at constant pressure is $\frac{23}{7} R$.

Question111

A sheet of steel is 40 cm long and 5 cm broad at $0^{\circ}\mathrm{C}$. The surface area of the sheet increases by $1.4\ \mathrm{cm}^2$ at $100^{\circ}\mathrm{C}$. Coefficient of linear expansion of steel is

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Options:

A. $1.9 \times 10^{-5} / {}^{\circ}\mathrm{C}$

B. $2.4 \times 10^{-5} / {}^{\circ}\mathrm{C}$

C. $3.5 \times 10^{-5} / {}^{\circ}\mathrm{C}$

D. $7 \times 10^{-5} / \mathrm{C}$

Answer: C

Solution:

To calculate the coefficient of linear expansion of steel, we start by considering the formula for the change in surface area due to thermal expansion:

$\Delta A = A_0 \cdot 2\alpha \cdot \Delta T$

where:

ΔA is the change in area

A_0 is the original area

α is the coefficient of linear expansion

ΔT is the change in temperature

Given:

Original length $L_0 = 40\,\text{cm}$

Original breadth $B_0 = 5\,\text{cm}$

$\Delta A = 1.4\,\text{cm}^2$

$\Delta T = 100^\circ\text{C} - 0^\circ\text{C} = 100^\circ\text{C}$

First, calculate the original area A_0:

$A_0 = L_0 \times B_0 = 40\,\text{cm} \times 5\,\text{cm} = 200\,\text{cm}^2$

Insert the known values into the formula to find α:

$1.4\,\text{cm}^2 = 200\,\text{cm}^2 \cdot 2\alpha \cdot 100^\circ\text{C}$

Solve for α:

$1.4 = 200 \times 200\alpha$

$\alpha = \frac{1.4}{200 \times 200}$

$\alpha = \frac{1.4}{40000}$

$\alpha = 0.000035\,/^\circ\text{C}$

Thus, the coefficient of linear expansion of steel is

$3.5 \times 10^{-5}/^\circ\text{C}$.

So, the correct option is C: $3.5 \times 10^{-5}/^\circ\text{C}$.

Question112

A quantity of heat ' Q ' is supplied to monoatomic ideal gas which expands at constant pressure. The fraction of heat converted into work is $\left[\gamma=\frac{\mathrm{C_p}}{\mathrm{C_v}}=\frac{5}{3}\right]$

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Options:

A. 3 : 5

B. 5 : 3

C. 2 : 5

D. 3 : 2

Answer: C

Solution:

When a quantity of heat ' Q ' is supplied to a monoatomic ideal gas that expands at constant pressure, the fraction of heat converted into work can be determined using the specific heat ratios. Given that the adiabatic index $\gamma=\frac{C_p}{C_v}=\frac{5}{3}$, we can reason as follows:

The relationship between the heat supplied (ΔQ) and the change in internal energy (ΔU) is given by the ratio of specific heats:

$\frac{\Delta Q}{\Delta U}=\gamma=\frac{5}{3}$

By rearranging to find the work done (W), we use:

$\frac{\Delta Q-\Delta U}{\Delta Q}=\frac{5-3}{5}$

Therefore, the fraction of heat converted into work is:

$\frac{W}{\Delta Q}=\frac{2}{5}$

This indicates that $\frac{2}{5}$ of the heat Q is converted into work during the expansion process.

Question113

What is the pressure of hydrogen in a cylinder of volume 10 litre if its total energy of translation is 7.5×10^3 J ?

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Options:

A. $5 \times 10^5 \mathrm{Nm}^{-2}$

B. $10^6 \mathrm{Nm}^{-2}$

C. $0.5 \times 10^5 \mathrm{Nm}^{-2}$

D. $5 \times 10^6 \mathrm{Nm}^{-2}$

Answer: A

Solution:

To determine the pressure of hydrogen in a cylinder with a volume of 10 liters, given that its total energy of translation is 7.5×10^3 J, we can use the following formula for pressure related to kinetic energy:

$$\text{Pressure} = \frac{2}{3} \times \frac{\text{Kinetic Energy}}{\text{Volume}}$$

Plug in the known values:

Kinetic energy $= 7.5 \times 10^3$ J

Volume $= 10 \text{ liters} = 10 \times 10^{-3} \mathrm{~m}^3$

$$\text{Pressure} = \frac{2 \times 7.5 \times 10^3}{3 \times \left(10 \times 10^{-3}\right)} = 5 \times 10^5 \mathrm{~N/m}^2$$

Therefore, the pressure of hydrogen in the cylinder is $5 \times 10^5 \mathrm{~N/m}^2$.

Question114

' N ' molecules of gas A, each having mass ' m ' and ' 2 N ' molecules of gas B , each of mass ' 2 m ' are contained in the same vessel which is at constant temperature ' T '. The mean square velocity of B is V^2 and mean square of x -component of A is ω^2. The value of $\frac{\omega^2}{V^2}$ is

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Options:

A. 3 : 2

B. 2 : 3

C. 1 : 2

D. 2 : 1

Answer: B

Solution:

The problem involves calculating the ratio of the mean square of the x-component of velocity of gas A to the mean square velocity of gas B. Both gases are kept at constant temperature T in a vessel.

Key Equations

Mean Square Velocity for a Gas:

Mean square velocity of a molecule $= \frac{3kT}{m}$

Gas A Data:

Let the mean square of the x-component of velocity of gas A be ω^2.

Thus, the mean square velocity of a molecule of gas A is $3\omega^2$.

Relation for Gas A:

$3\omega^2 = \frac{3kT}{m} \quad \text{(i)}$

Gas B Data:

Mean square velocity of a molecule of gas B is V^2.

Relation for Gas B:

$V^2 = \frac{3kT}{2m} \quad \text{(ii)}$

Calculation

Using equations (i) and (ii):

$\frac{3\omega^2}{V^2} = \frac{3kT}{m} \times \frac{2m}{3kT}$

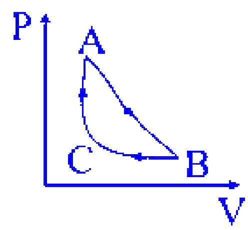
Simplifying the expression:

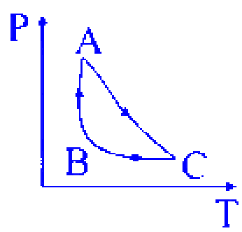
$\frac{\omega^2}{V^2} = \frac{2}{3}$

Thus, the ratio $\frac{\omega^2}{V^2}$ is $\frac{2}{3}$.

Question115

The $\mathrm{p}-\mathrm{V}$ diagram for a fixed mass of an ideal gas undergoing cyclic process is as shown in figure. AB represents isothermal process and CA represents adiabatic process. Which one of the following graphs represents the p-T diagram of this cyclic process?





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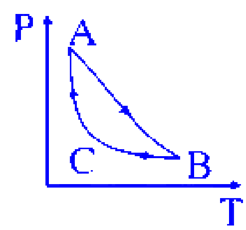

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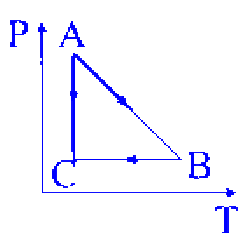
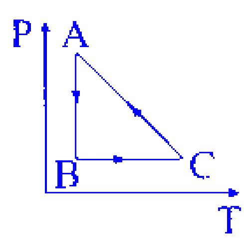


(G)



(H)

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Options:

A. (G)

B. (F)

C. (H)

D. (E)

Answer: D

Solution:

Since AB is an isothermal process, The P-T diagram must be perpendicular to X -axis denoting temperature.

Question116

Two cylinders A and B fitted with piston contain equal amount of an ideal diatomic as at temperature ' T ' K . The piston of cylinder 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 temperature of the gas in A is ' $\mathrm{dT_A}$ ', then the rise in temperature of the gas in cylinder B is $\left(\gamma=\frac{C_p}{C_v}\right)$

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Options:

A. $\mathrm{2dt_A}$

B. $\frac{\mathrm{dT_A}}{2}$

C. $\gamma \mathrm{dT_A}$

D. $\frac{\mathrm{dT}_A}{\gamma}$

Answer: C

Solution:

When heat is applied to both cylinders A and B, they behave differently due to the piston's conditions. In cylinder A, the piston is free to move, so the heat is applied at constant pressure. Meanwhile, in cylinder B, the piston is fixed, meaning heat is applied at constant volume.

To find the relationship between the rise in temperature for cylinders A and B, note that the amount of heat added to both cylinders is the same:

$Q_A = Q_B$

For cylinder A (constant pressure), the heat added is given by:

$Q_A = nC_p\, dT_A$

For cylinder B (constant volume), the heat added is:

$Q_B = nC_v\, dT_B$

Since $Q_A = Q_B$, equate the two expressions:

$nC_p\, dT_A = nC_v\, dT_B$

Thus, the expression for the temperature rise in cylinder B becomes:

$dT_B = \frac{C_p}{C_v}\, dT_A = \gamma\, dT_A$

Therefore, the increase in temperature of the gas in cylinder B is $\gamma\, dT_A$, where γ is the heat capacity ratio $\frac{C_p}{C_v}$.

Question117

A metal rod having coefficient of linear expansion $2 \times 10^{-5} / ^\circ\mathrm{C}$ is 0.75 m long at $45^\circ\mathrm{C}$. When the temperature rises to $65^\circ\mathrm{C}$, the increase in length of the rod will be

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Options:

A. 3.0 mm

B. 0.75 mm

C. 0.30 mm

D. 0.15 mm

Answer: C

Solution:

To find the increase in length of a metal rod due to temperature change, you can use the formula:

$\mathrm{d}l = \alpha \times l \times \mathrm{dt}$

where:

α is the coefficient of linear expansion.

l is the original length of the rod.

dt is the change in temperature.

For this problem:

$\alpha = 2 \times 10^{-5} / {}^{\circ}\mathrm{C}$

$l = 0.75\,\mathrm{m}$

The temperature change, $\mathrm{dt} = 65^{\circ}\mathrm{C} - 45^{\circ}\mathrm{C} = 20^{\circ}\mathrm{C}$

Substitute these values into the formula:

$\mathrm{d}l = 2 \times 10^{-5} \times 0.75 \times 20$

$\mathrm{d}l = 0.3 \times 10^{-3}\mathrm{m} = 0.30\,\mathrm{mm}$

Thus, the increase in length of the rod is 0.30 mm.

Question118

The ratio of the velocity of sound in hydrogen gas $\left(\gamma = \frac{7}{5}\right)$ to that in helium gas $\left(\gamma = \frac{5}{3}\right)$ at the same temperature is

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Options:

A. $1 : 1$

B. $7 : 3$

C. $21 : 25$

D. $\sqrt{42} : 5$

Answer: D

Solution:

The velocity of sound in a gas is given by the formula:

$$v = \sqrt{\frac{\gamma RT}{M}}$$

where:

v is the velocity of sound,

γ is the adiabatic index (ratio of specific heats C_p/C_v),

R is the universal gas constant,

T is the absolute temperature,

M is the molar mass of the gas.

To find the ratio of the velocities of sound in hydrogen and helium at the same temperature, we'll first write the expression for each gas:

For hydrogen ($\gamma = \frac{7}{5}$, $M_H = 2$, as hydrogen is H_2):

$$v_H = \sqrt{\frac{\frac{7}{5} \cdot R \cdot T}{2}} = \sqrt{\frac{7RT}{10}}$$

For helium ($\gamma = \frac{5}{3}$, $M_{He} = 4$):

$$v_{He} = \sqrt{\frac{\frac{5}{3} \cdot R \cdot T}{4}} = \sqrt{\frac{5RT}{12}}$$

Now, let's find the ratio $\frac{v_H}{v_{He}}$:

$$\frac{v_H}{v_{He}} = \frac{\sqrt{\frac{7RT}{10}}}{\sqrt{\frac{5RT}{12}}}$$

This simplifies to:

$$\frac{v_H}{v_{He}} = \sqrt{\frac{7RT}{10} \cdot \frac{12}{5RT}} = \sqrt{\frac{7 \cdot 12}{10 \cdot 5}} = \sqrt{\frac{84}{50}} = \sqrt{\frac{42}{25}}$$

Therefore, the ratio is:

$\sqrt{42} : 5$

Option D is the correct answer.

Question119

Two spheres S_1 and S_2 have same radii but temperatures T_1 and T_2 respectively. Their emissive power is same and emissivity in the ratio 1:4. Then the ratio $T_1 : T_2$ is

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Options:

A. $2 : 1$

B. $\sqrt{2} : 1$

C. $1 : \sqrt{2}$

D. $1 : 2$

Answer: B

Solution:

Given that two spheres, S_1 and S_2, have the same radius but different temperatures T_1 and T_2, their emissive powers are the same with emissivities in the ratio $1 : 4$. We need to determine the ratio $T_1 : T_2$.

First, recall that emissive power is given by the formula:

$$\frac{Q_1}{A_1 t} = \frac{Q_2}{A_2 t}$$

Since the radii of the spheres are the same, it follows that:

$$A_1 = A_2$$

Thus, we have:

$$Q_1 = Q_2$$

Using the Stefan-Boltzmann law, which states that emissive power E is given by:

$$E = e\sigma AT^4$$

We can write:

$$e_1\sigma AT_1^4 = e_2\sigma AT_2^4$$

Given the emissivity ratio $\frac{e_2}{e_1} = \frac{4}{1}$, we have:

$$\frac{T_1^4}{T_2^4} = \frac{e_2}{e_1} = \frac{4}{1}$$

Taking the fourth root on both sides, we find:

$$\frac{T_1}{T_2} = \left(\frac{4}{1}\right)^{\frac{1}{4}} = \frac{\sqrt{2}}{1}$$

Hence, the ratio $T_1 : T_2$ is $\sqrt{2} : 1$.

Question120

Two gases A and B having same initial state ($\mathrm{P}, \mathrm{V}, \mathrm{n}, \mathrm{T}$). Now gas A is compressed to $\frac{\mathrm{V}}{8}$ by isothermal process and other gas B is compressed to $\frac{\mathrm{V}}{8}$ by adiabatic process. The ratio of final pressure of gas A and B is (Both gases are monoatomic, $\gamma=5/3$)

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Options:

A. $\frac{1}{8}$

B. $\frac{1}{4}$

C. $\frac{1}{64}$

D. $\frac{1}{12}$

Answer: B

Solution:

For isothermal process (Gas A):

In an isothermal process, the product of pressure and volume remains constant:

$P_1 V_1=P_2 V_2$

Given:

$P_0 \cdot\left(8 V_0\right)=P_2 \cdot V_0$

Solving this relation gives:

$P_2=8 P_0$

For adiabatic process (Gas B):

In an adiabatic process, $P V^\gamma=$ constant.

Thus:

$\frac{P_2}{P_1}=(8)^\gamma$

Therefore:

$P_2 = (8)^\gamma P_0$

The ratio of the final pressures of gas B to gas A is:

$\frac{(P_2)_B}{(P_1)_A} = \frac{(8)^\gamma P_0}{8P_0} = (8)^{\gamma-1}$

Given $\gamma = \frac{5}{3}$:

$\frac{(P_2)_B}{(P_1)_A} = 8^{2/3} = \sqrt[3]{64} = 4$

Thus, the inverse ratio is:

$\frac{(P_1)_A}{(P_2)_B} = \frac{1}{4}$

Question121

Two vessels separately contain two ideal gases A and B at the same temperature, pressure of A being twice that of B . Under such conditions, the density of A is found to be 1.5 times the density of B. The ratio of molecular weights of A and B is

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Options:

A. 1 : 2

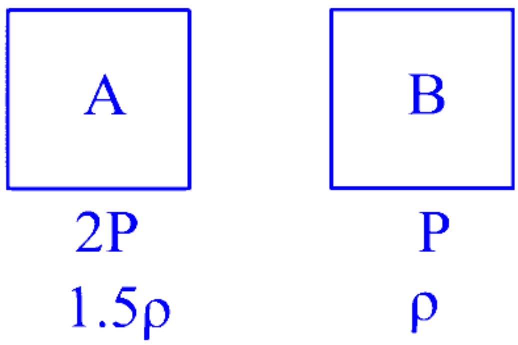
B. 2 : 3

C. 3 : 4

D. 2 : 1

Answer: C

Solution:



For an ideal gas, $\mathrm{PV}=\mathrm{RT}$ and $\mathrm{M}=\rho \mathrm{V}$

$$\therefore \quad \frac{P M}{\rho}=R T$$

$$\therefore \quad \frac{P_A M_A}{\rho_A}=\frac{P_B M_B}{\rho_B}$$

$$\frac{M_A}{M_B}=\frac{\rho_A}{\rho_B} \times \frac{P_B}{P_A}=\frac{3}{2} \times \frac{1}{2}=\frac{3}{4}$$

Question122

An insulated container contains a diatomic gas of molar mass ' m '. The container is moving with velocity ' V ', if it is stopped suddenly, the change in temperature is ($R=$ gas constant)

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Options:

A. $\frac{\mathrm{mV}^2}{3 \mathrm{R}}$

B. $\frac{\mathrm{mV}^2}{5 \mathrm{R}}$

C. $\frac{\mathrm{mV}}{7 \mathrm{R}}$

D. $\frac{5 m V}{3 R}$

Answer: B

Solution:

In an insulated container containing a diatomic gas with molar mass 'm', moving at velocity 'V', if the container is stopped suddenly, the change in temperature can be calculated as follows:

Kinetic Energy (K.E.) of the Gas:

The kinetic energy of the gas is given by:

$\text{K.E.} = n\left(\frac{1}{2}mV^2\right)$

Internal Energy Change (ΔU):

When the container is stopped, the change in internal energy is expressed as:

$\Delta U = nC_v\Delta T$

For a diatomic gas, the specific heat capacity at constant volume is:

$C_v = \frac{5}{2}R$

Energy Conservation:

Since energy is conserved when the container is stopped, the change in internal energy equals the initial kinetic energy:

$\Delta U = \text{K.E.}$

Solving for Change in Temperature (ΔT):

Substituting the expressions from above, we have:

$n\frac{5}{2}R\Delta T = n\left(\frac{1}{2}mV^2\right)$

Cancelling 'n' from both sides and solving for ΔT:

$\Delta T = \frac{mV^2}{5R}$

This expression gives the change in temperature of the gas when the container is abruptly stopped.

Question123

Rails of material of steel are laid with gaps to allow for thermal expansion. Each track is 10 m long, when laid at temperature 17°C. The maximum temperature that can be reached is 45°C. The gap to be kept between the two segments of railway track is

$$\left(\alpha_{\text{steel}} \quad = 1.3 \times 10^{-5}/^\circ\text{C}\right)$$

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Options:

A. 1.68 mm

B. 2.06 mm

C. 3.64 mm

D. 4.32 mm

Answer: C

Solution:

To find the gap that should be left between the two segments of the railway track to accommodate for thermal expansion, we use the formula for linear expansion:

$\Delta L = L \times \alpha \times \Delta T$

where:

ΔL is the change in length,

L is the original length of the rail,

α is the coefficient of linear expansion for steel,

ΔT is the change in temperature.

Given:

$L = 10\,\text{m} = 10,000\,\text{mm}$

$\alpha = 1.3 \times 10^{-5}/^{\circ}\text{C}$

Initial temperature: $T_1 = 17^{\circ}\text{C}$

Final temperature: $T_2 = 45^{\circ}\text{C}$

Now, calculate the change in temperature:

$\Delta T = T_2 - T_1 = 45 - 17 = 28^{\circ}\text{C}$

Next, substitute these values into the formula for linear expansion:

$\Delta L = 10,000 \times 1.3 \times 10^{-5} \times 28$

Calculating further:

$\Delta L = 10,000 \times 1.3 \times 28 \times 10^{-5}$

$\Delta L = 10,000 \times 0.000364$

$\Delta L = 3.64\,\text{mm}$

Therefore, the gap to be kept between the two segments of the railway track is **3.64 mm**.

The correct answer is **Option C: 3.64 mm**.

Question124

In an adiabatic process for an ideal gas, the relation between the universal gas constant ' R ' and specific heat at constant volume ' $\mathrm{C_v}$ ' is $R=0.4C_v$. The pressure ' P ' of the gas is proportional to the temperature ' T ', of the gas as T^k. The value of constant ' K ' is

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Options:

A. $\frac{7}{2}$

B. $\frac{7}{3}$

C. 5

D. 5

Answer: A

Solution:

In an adiabatic process for an ideal gas, where the universal gas constant R is related to the specific heat at constant volume $\mathrm{C_v}$ as $R=0.4\mathrm{C_v}$, the pressure P is proportional to the temperature T raised to the power K, or $P\propto T^K$.

For such a process, the relationship can be expressed as:

$\mathrm{PT}^{-K}=\text{constant}$

In an adiabatic process for an ideal gas, another important relationship is:

$\mathrm{PT}^{\frac{\gamma}{1-\gamma}}=\text{constant}$

From these, we deduce:

$\frac{\gamma}{1-\gamma}=-K \quad$ .... (i)

Furthermore, the specific heat at constant pressure $\mathrm{C_p}$ can be expressed as:

$\mathrm{C_p}=\mathrm{C_v}+R$

$C_p = C_v + 0.4C_v$

$C_p = 1.4C_v$

The adiabatic index γ is given by:

$\gamma = \frac{C_p}{C_v} = 1.4 \quad \ldots \text{(ii)}$

By combining (i) and (ii), we have:

$\frac{\gamma}{1-\gamma} = \frac{1.4}{1-1.4} = \frac{-1.4}{-0.4} = \frac{-14}{4} = \frac{-7}{2}$

Thus, solving for K:

$\frac{-7}{2} = -K$

$K = \frac{7}{2}$

Question125

The black discs x, y and z have radii $1 \mathrm{~m}, 2 \mathrm{~m}$ and 3 m respectively. The wavelengths corresponding to maximum intensity are $200 \mathrm{~nm}, 300 \mathrm{~nm}$ and 400 nm respectively. The relation between emissive power E_x, E_y and E_z is

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Options:

A. $E_x > E_y > E_z$

B. $E_x < E_y < E_z$

C. $E_x = E_y = E_z$

D. $E_y > E_x < E_z$

Answer: A

Solution:

The black discs x, y, and z have radii of 1 m, 2 m, and 3 m, respectively. The wavelengths corresponding to maximum intensity are 200 nm, 300 nm, and 400 nm, respectively. Here, we explore the relationship between the emissive power E_x, E_y, and E_z for these discs.

Emissive Power

The formula for emissive power is given by:

$E = \sigma A T^4 \quad \Rightarrow \quad E \propto A T^4$

Where:

A is the area of the disc.

T is the absolute temperature.

σ is the Stefan-Boltzmann constant.

Area Calculation

The area A of a disc is given by $A = \pi R^2$. Therefore:

$A \propto R^2$

Given:

$R_1 = 1\,\text{m}$

$R_2 = 2\,\text{m}$

$R_3 = 3\,\text{m}$

The areas are proportional as follows:

$A_x : A_y : A_z \quad \text{proportional to} \quad 1:4:9 \quad \text{... (i)}$

Temperature Analysis Using Wien's Displacement Law

By Wien's displacement law, we have:

$\lambda_{\max} T = \text{constant} \quad \Rightarrow \quad T \propto \frac{1}{\lambda}$

Given maximum wavelengths:

$\lambda_{\max 1} = 200\,\text{nm}$

$\lambda_{\max 2} = 300\,\text{nm}$

$\lambda_{\max 3} = 400\,\text{nm}$

The wavelengths are proportional as follows:

$\lambda_x : \lambda_y : \lambda_z \quad \text{proportional to} \quad 2:3:4$

Thus the temperatures are:

$\frac{1}{T_x} : \frac{1}{T_y} : \frac{1}{T_z} \quad \text{proportional to} \quad 2:3:4$

Therefore, the temperatures are proportional as:

$T_x : T_y : T_z \quad \text{proportional to} \quad \frac{1}{2} : \frac{1}{3} : \frac{1}{4}$

Simplified, this gives:

$T_x : T_y : T_z$ proportional to 6 : 4 : 3 ... (ii)

Comparison of Emissive Powers

We compare the product AT^4 for the discs:

For disc x: $A_x T_x^4 = 1 \times (6)^4 = 1296$

For disc y: $A_y T_y^4 = 4 \times (4)^4 = 1024$

For disc z: $A_z T_z^4 = 9 \times (3)^4 = 729$

Thus, the relationship between the emissive powers is:

$E_x > E_y > E_z$

Question126

For a gas, $\frac{\mathrm{R}}{\mathrm{C_v}} = 0.4$ where R is the universal gas constant and ' $\mathrm{C_V}$ ' is molar specific heat at constant volume. The gas is made up of molecules which are

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Options:

A. rigid diatomic.

B. monoatomic.

C. non-rigid diatomic.

D. polyatomic.

Answer: A

Solution:

Given: $\frac{R}{C_v} = 0.4$

To determine the type of gas molecules, we start with the given ratio:

Finding C_v:

$C_v = \frac{R}{0.4} = \frac{5R}{2}$

Calculate C_p:

$C_p = C_v + R = \frac{5R}{2} + R = \frac{7R}{2}$

Determine γ (the heat capacity ratio):

$\gamma = \frac{C_p}{C_v} = \frac{\frac{7R}{2}}{\frac{5R}{2}} = \frac{7}{5}$

The value of $\gamma = \frac{7}{5}$ is characteristic of gases made up of rigid diatomic molecules. Hence, the gas consists of rigid diatomic molecules.

Question127

In a thermodynamic system ' ΔU ' represents the increase in internal energy and ' W ' the work done by the system. Which of the following statement is true?

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Options:

A. $\Delta \mathrm{U} = -\mathrm{W}$ in an adiabatic process.

B. $\Delta \mathrm{U} = \mathrm{W}$ in an isothermal process.

C. $\Delta \mathrm{U} = -\mathrm{W}$ in an isothermal process.

D. $\Delta \mathrm{U} = \mathrm{W}$ in an adiabatic process.

Answer: A

Solution:

In an isothermal process, the change in internal energy, ΔU, is zero. According to the first law of thermodynamics, the relationship is given by:

$\Delta Q = \Delta U + W$

For an adiabatic process, where no heat is exchanged with the surroundings, the heat transfer, ΔQ, is zero. Therefore, the equation simplifies to:

$\Delta U = -W$

Question128

Rate of radiation by a black body is ' R ' at temperature 'T'. Another body has same area but emissivity is 0.2 and temperature 3T. Its rate of radiation is

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Options:

A. $(162) R$

B. (81)R

C. $(16.2) R$

D. (8.1)R

Answer: C

Solution:

To determine the rate of radiation for a black body and another body with the same area but different emissivity and temperature, let's review the calculations.

Rate of Radiation for a Black Body

The formula for the rate of radiation from a black body is given by:

$$R=\left(\frac{d Q}{d t}\right)_1=e A \sigma T^4$$

Since the emissivity (e) of a black body is 1, the equation simplifies to:

$$R=A \sigma T^4$$

Rate of Radiation for Another Body

Now, consider another body with the same surface area but emissivity $e^{\prime}$ of 0.2 and temperature $3 T$. The rate of radiation formula for this body is:

$$\left(\frac{d Q}{d t}\right)_2=e^{\prime} A \sigma\left(T^{\prime}\right)^4$$

Substituting the given values:

$$\left(\frac{d Q}{d t}\right)_2=0.2 A \sigma(3 T)^4$$

Simplifying the equation:

$$\left(\frac{dQ}{dt}\right)_2 = 0.2A\sigma \cdot 81T^4$$

$$\left(\frac{dQ}{dt}\right)_2 = 16.2A\sigma T^4$$

Since $A\sigma T^4$ is equivalent to the rate of radiation R from the black body, we can write:

$$\left(\frac{dQ}{dt}\right)_2 = 16.2R$$

Thus, the rate of radiation for the second body is $16.2R$.

Question129

A Carnot's cycle operating between $T_H = 600$ K and $T_c = 300$ K produces 1.5 kJ of mechanical work per cycle. The heat transferred to the engine by the reservoir is

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Options:

A. 2.5 kJ

B. 3.0 kJ

C. 3.5 kJ

D. 4.0 kJ

Answer: B

Solution:

To find the heat transferred to the engine, we start by determining the efficiency of a Carnot engine operating between two temperatures, $T_H = 600\,\mathrm{K}$ and $T_C = 300\,\mathrm{K}$.

The efficiency η of a Carnot engine is given by:

$$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{300}{600}$$

This simplifies to:

$$\eta = \frac{1}{2}$$

Efficiency is also defined as the ratio of the work done per cycle (W) to the heat transferred to the engine per cycle (Q):

$\eta = \frac{W}{Q}$

Given that the work done per cycle is $1.5\,\mathrm{kJ}$:

$\frac{1}{2} = \frac{1.5}{Q}$

Solving for Q:

$Q = 1.5 \times 2 = 3\,\mathrm{kJ}$

Thus, the heat transferred to the engine per cycle is $3\,\mathrm{kJ}$.

Question130

An ordinary body cools from ' $4\theta'$ ' to ' $3\theta'$ ' in ' t ' minutes. The temperature of that body after next 't' minutes is (Assume Newton's law of cooling and room temperature is θ)

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Options:

A. $\frac{9\theta}{4}$

B. $\frac{2\theta}{5}$

C. $\frac{5\theta}{3}$

D. $\frac{7\theta}{3}$

Answer: D

Solution:

According to Newton's law of cooling, the rate at which an object cools is proportional to the difference between its temperature and the ambient temperature. The formula is:

$\frac{\theta_1-\theta_2}{t} = K\left[\frac{\theta_1+\theta_2}{2} - \theta_0\right]$

where:

θ_0 is the ambient (surrounding) temperature,

θ_1 and θ_2 are the initial and final temperatures of the body,

K is the cooling constant,

t is the time.

Applying this to the problem at hand, we have:

$$\therefore \quad \frac{4\theta - 3\theta}{t} = K\left[\frac{4\theta + 3\theta}{2} - \theta\right]$$

$$\frac{\theta}{t} = K \times \frac{5\theta}{2} \quad \text{.... (i)}$$

Solving for K, we find: $K = \frac{2}{5t}$

After another t minutes, let the new temperature be x. Then:

$$\therefore \quad \frac{3\theta - x}{t} = \frac{2}{5t}\left[\frac{3\theta + x}{2} - \theta\right] \quad \ldots \text{[using (i)]}$$

$$\therefore \quad 3\theta - x = \frac{3\theta + x - 2\theta}{5}$$

$$\therefore \quad 15\theta - 5x = x + \theta$$

$$\therefore \quad 6x = 14\theta$$

$$\therefore \quad x = \frac{7\theta}{3}$$

Therefore, the temperature of the body after the next t minutes is $\frac{7\theta}{3}$.

Question131

A black sphere has radius R whose rate of radiation is E at temperature T . If radius is made half and temperature 4 T , the rate of radiation will be

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Options:

A. 64 E

B. 32 E

C. 16 E

D. 8 E

Answer: A

Solution:

To determine the change in the rate of radiation when the radius and temperature of a black sphere are altered, consider these steps:

Initial Formula for Radiation:

The rate of radiation E is given by the formula:

$E = eA\sigma T^4$

where e is the emissivity, A is the surface area, σ is the Stefan-Boltzmann constant, and T is the temperature.

Surface Area of a Sphere:

For a sphere, the surface area A is:

$A = 4\pi R^2$

Thus, the initial radiation rate is:

$E = e(4\pi R^2)\sigma T^4$

Revised Conditions:

The sphere's radius is reduced to $\frac{R}{2}$, and the temperature is increased to $4T$.

New Radiation Formula:

With the new radius and temperature, let the new rate of radiation be E_2. Substitute the new values into the radiation formula:

$E_2 = e\left(4\pi\left(\frac{R}{2}\right)^2\right)\sigma(4T)^4$

Comparing Both Rates:

To find the ratio of the initial and new radiation rates:

$\frac{E}{E_2} = \frac{R^2T^4}{\left(\frac{R}{2}\right)^2(4T)^4}$

Calculation:

Simplify the ratio:

$\frac{E}{E_2} = \frac{R^2T^4}{\frac{R^2}{4}\cdot 256T^4} = \frac{1}{\frac{1}{4}\cdot 256} = \frac{1}{64}$

Therefore, $E_2 = 64E$.

From these calculations, when the radius is halved and the temperature is increased by four times, the rate of radiation increases to 64 times the original rate.

Question132

Ordinary bodies P and Q radiate maximum energy with wavelength difference 3μ m. The absolute temperature of body P is four times that of Q. The wavelength at which body Q radiates maximum energy is

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Options:

A. 2 μm

B. 4 μm

C. 6 μm

D. 8 μm

Answer: B

Solution:

To solve the problem, we start by noting the given information:

The difference in the wavelengths at which bodies P and Q radiate maximum energy is 3μm. This can be expressed as:

$\lambda_{\mathrm{Q}} - \lambda_{\mathrm{P}} = 3\mu\mathrm{m}$ .... (i)

According to Wien's law, the relationship between the wavelength of maximum emission (λ) and temperature (T) for a black body is given by:

$\lambda_P T_P = \lambda_Q T_Q$

We are informed that the temperature T_P of body P is four times that of body Q (T_Q), therefore:

$\lambda_P \cdot 4T_Q = \lambda_Q \cdot T_Q$

Simplifying the equation above gives us:

$\lambda_Q = 4\lambda_P$ .... (ii)

Using equation (ii), we substitute back into equation (i):

Substitute $\lambda_Q = 4\lambda_P$ into $\lambda_Q - \lambda_P = 3\mu$m:

$4\lambda_P - \lambda_P = 3\mu$m

Solving for λ_P:

$3\lambda_P = 3\mu\text{m} \implies \lambda_P = 1\mu\text{m}$

Finally, using $\lambda_P = 1\mu\text{m}$ in the expression $\lambda_Q = 4\lambda_P$:

Solve for λ_Q:

$\lambda_Q = 4 \times 1\mu\text{m} = 4\mu\text{m}$

Thus, the wavelength at which body Q radiates maximum energy is 4μm.

Question133

The average force applied on the wall of a closed container depends as T^{x} where T is the temperature of an ideal gas. The value of x is

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Options:

A. 0.5

B. 1

C. 2

D. 1.5

Answer: B

Solution:

The average force applied on the wall of a closed container can be related to the temperature of an ideal gas using its dependency on temperature T^{x}. To find the value of x, we can derive it step by step:

The pressure P is defined as force F per unit area A:

$P = \frac{F}{A}$

Therefore, pressure is proportional to force:

$P \propto F \quad \text{.... (i)}$

According to the ideal gas law, the pressure P is also given by:

$P = \frac{nRT}{V}$

where n is the number of moles, R is the ideal gas constant, T is the temperature, and V is the volume. If the volume V is constant:

$P \propto T$ .... (ii)

Combining equations (i) and (ii), we find the relationship between force and temperature:

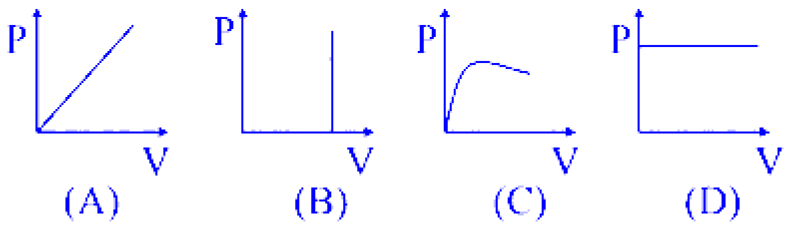
$F \propto T^x$

From the proportionality derived:

$x = 1$

Question134

Which of the following graphs between pressure and volume correctly show isochoric process?



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Options:

A. D

B. A

C. C

D. B

Answer: D

Solution:

For an isochoric process, the volume remains constant while the pressure changes, so the P-V graph is a vertical straight line (constant V).

In the given options, only graph (B) shows a vertical line at fixed volume, so the correct answer is **B**.

Question135

Initial pressure and volume of a gas are ' P ' and ' V ' respectively. First its volume is expanded to ' 4 V ' by isothermal process and then again its volume is reduced to ' V ' by adiabatic process then its final pressure if $\left(\gamma=\frac{3}{2}\right)$

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Options:

A. P

B. 2P

C. 3P

D. 4P

Answer: B

Solution:

To determine the final pressure after the given processes, we can follow these steps:

Isothermal Expansion:

Initial pressure and volume of the gas are P and V, respectively.

The gas undergoes an isothermal expansion to a volume $4V$.

For an isothermal process, the relationship between pressure and volume is given by:

$P_1V_1 = P_2V_2$

Substituting the given values:

$P \cdot V = P_2 \cdot 4V$

Solving for P_2, we get:

$P_2 = \frac{P}{4}$

Adiabatic Compression:

Next, the gas undergoes adiabatic compression back to the original volume V.

For an adiabatic process, the equation is:

$P_2 V_2^{\gamma} = P_3 V_3^{\gamma}$

Given that $V_2 = 4V$, $V_3 = V$, and $\gamma = \frac{3}{2}$:

$\frac{P}{4} \cdot (4V)^{\gamma} = P_3 \cdot V^{\gamma}$

Substituting $\gamma = \frac{3}{2}$, this becomes:

$\frac{P}{4} \cdot (4V)^{3/2} = P_3 \cdot V^{3/2}$

Simplifying further:

$\frac{P}{4} \cdot 4^{3/2} = P_3$

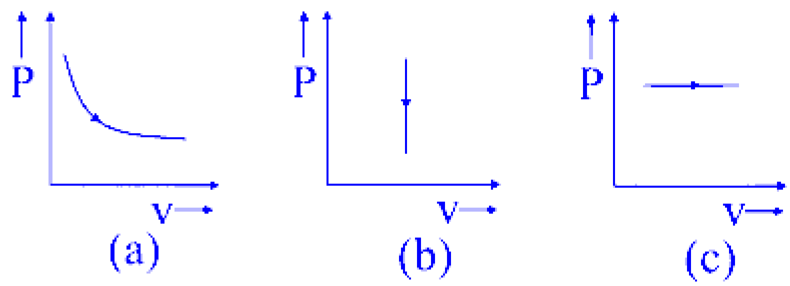
Since $4^{3/2} = 8$, we have:

$P_3 = \frac{P}{4} \times 8 = 2P$

Thus, the final pressure after the entire process is $2P$.

Question136

The P-V diagrams for particular gas of different thermodynamic processes are given by



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Options:

A. Figure (a) and (b) show isobaric curve and isothermal curve respectively.

B. Figure (a) and (c) show isothermal curve and isochoric curve respectively.

C. Figure (b) and (c) show isobaric curve and isochoric curve respectively.

D. Figure (a) and (c) show isothermal curve and isobaric curve respectively.

Answer: D

Solution:

$\mathrm{PV}=\mathrm{nRT}$

For an isothermal curve, T is constant, hence

$\mathrm{PV}=$ constant.

For an isobaric curve, V remains constant.For an isochoric curve, P remains constant.

Question137

An ideal gas $(\gamma=1.5)$ is expanded adiabatically.To reduce root mean square velocity of molecules two times, the gas should be expanded

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Options:

A. 20 times

B. 16 times

C. 12 times

D. 8 times

Answer: B

Solution:

To understand how the expansion of an ideal gas affects the root mean square (r.m.s) velocity of its molecules during an adiabatic process, let's break down the steps:

Relationship of r.m.s. Velocity and Temperature:

The root mean square velocity (v) of gas molecules is proportional to the square root of its absolute temperature (T), given by:

$v \propto \sqrt{T}$

Therefore, the ratio of the r.m.s velocities under two different temperatures is:

$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$ (Equation 1)

Condition for Reduced r.m.s. Velocity:

If the r.m.s. velocity is reduced by half, then:

$v_2 = \frac{v_1}{2}$

Substituting this into Equation 1 gives:

$\frac{1}{2} = \sqrt{\frac{T_2}{T_1}} \quad \Rightarrow \quad \frac{T_1}{T_2} = 4$ (Equation 2)

Adiabatic Expansion:

For an adiabatic process, which conserves internal energy without heat exchange, the relationship is:

$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

Substituting the temperature ratio from Equation 2, we have:

$\left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{T_1}{T_2} = 4$

Solving for Volume Expansion:

Using $\gamma = 1.5$, the equation becomes:

$\left(\frac{V_2}{V_1}\right)^{0.5} = 4$

Solving for $\frac{V_2}{V_1}$, we square both sides:

$\frac{V_2}{V_1} = 16$

Thus, the gas should be expanded 16 times to reduce the r.m.s. velocity of its molecules to half its initial value through adiabatic expansion.

Question138

A black body radiates power ' P ' and maximum energy is radiated by it at a wavelength λ_0. The temperature of the black body is now so changed that it radiates maximum energy at the wavelength $\frac{\lambda_0}{4}$. The power radiated by it at new temperature is

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Options:

A. 64 P

B. 256 P

C. 4 P

D. 16 P

Answer: B

Solution:

According to Wien's Displacement Law:

$\lambda_{\max} \cdot T=$ constant

Given this, we can relate the initial and final temperatures using the wavelengths:

$\frac{T_1}{T_2}=\frac{\lambda_{\max, 2}}{\lambda_{\max, 1}}=\frac{\frac{\lambda_0}{4}}{\lambda_0}=\frac{1}{4}$

The power radiated by a black body is given by Stefan-Boltzmann law:

$P=\sigma A T^4$

We need to determine the ratio of the powers:

$\frac{P_1}{P_2}=\left(\frac{T_1}{T_2}\right)^4=\left(\frac{1}{4}\right)^4=\frac{1}{256}$

Solving for P_2 gives:

$P_2=256 \cdot P_1=256 \cdot P$

Thus, the power radiated at the new temperature is $256 P$.

Question139

The temperature of a liquid falls from 365 K to 359 K in 3 minutes. The time during which temperature of this liquid falls from 342 K to 338 K is [Let the room temperature be 296 K]

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Options:

A. 6 min

B. 4 min

C. 3 min

D. 2 min

Answer: C

Solution:

To determine the time it takes for the temperature of a liquid to fall from 342 K to 338 K, we use Newton's law of cooling:

$$\frac{T_1-T_2}{t}=K\left(\frac{T_1+T_2}{2}-T_0\right)$$

where T_0 is the room temperature.

Given:

First scenario: Temperature falls from 365 K to 359 K in 3 minutes.

Using the equation:

$$\frac{365-359}{3}=K\left[\frac{365+359}{2}-296\right]$$

Simplifying:

$$\frac{6}{3}=K\left[\frac{724}{2}-296\right]$$

$$2=K(362-296)$$

$$K=\frac{1}{33}$$

Second scenario: Temperature falls from 342 K to 338 K in t minutes.

Using the equation:

$$\frac{342-338}{t}=\frac{1}{33}\left[\frac{342+338}{2}-296\right]$$

Simplifying:

$$\frac{4}{t}=\frac{1}{33}\left[\frac{680}{2}-296\right]$$

$$\frac{4}{t}=\frac{4}{3}$$

Solving for t:

$t=3$ minutes

Therefore, the time required for the temperature to drop from 342 K to 338 K is 3 minutes.

Question140

In an isobaric process of an ideal gas, the ratio of work done by the system (W) during the expansion and the heat exchanged (Q) is $\left(\gamma=\frac{\mathrm{C}_{\mathrm{p}}}{\mathrm{C}_{\mathrm{v}}}\right)$

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Options:

A. γ

B. $\gamma-1$

C. $\frac{\gamma}{\gamma-1}$

D. $\frac{\gamma-1}{\gamma}$

Answer: D

Solution:

In an isobaric process for an ideal gas, we need to determine the ratio of the work done by the system (W) during expansion to the heat exchanged (Q). Here, $\gamma=\frac{C_p}{C_v}$ represents the ratio of specific heats.

For an isobaric process, the formulas are as follows:

Heat exchanged, $Q=n C_p \Delta T$

Work done, $W=n\left(C_p-C_v\right) \Delta T$

Now, let's find the ratio of work done to heat exchanged:

$$\begin{aligned} \frac{W}{Q} & =\frac{n\left(C_p-C_v\right) \Delta T}{n C_p \Delta T} \\ & =\frac{C_p-C_v}{C_p} \\ & =1-\frac{C_v}{C_p}\end{aligned}$$

Given that $\gamma=\frac{C_p}{C_v}$, we can substitute this relationship into the equation:

$1-\frac{C_v}{C_p}=1-\frac{1}{\gamma}=\frac{\gamma-1}{\gamma}$

Thus, the ratio of work done to heat exchanged in an isobaric process is $\frac{\gamma-1}{\gamma}$.

Question141

Three identical metal spheres (of same surface area) have red, black and white colors and they are heated up to same temperature. They are allowed to cool. Arrange them from maximum rate of cooling to minimum rate of cooling

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Options:

A. black, red, white

B. white, red, black,

C. red, black, white

D. red, white, black

Answer: A

Solution:

The cooling of each sphere is mainly due to radiation and is described by the Stefan–Boltzmann law:

$P = \epsilon \sigma A(T^4 - T_{\text{ambient}}^4)$

where:

ϵ is the emissivity of the surface,

σ is the Stefan–Boltzmann constant,

A is the surface area,

T is the temperature of the sphere,

T_{ambient} is the ambient temperature.

Since all spheres have the same surface area and are at the same temperature, the rate of cooling is directly proportional to their emissivities. Typically:

Black surfaces have high emissivity (close to 1),

Red surfaces generally have a moderate emissivity,

White surfaces tend to have low emissivity because they are more reflective.

Thus, the sphere with black color will radiate energy (and cool) the fastest, followed by the red sphere, while the white sphere cools the slowest.

Therefore, the order from maximum rate of cooling to minimum rate is:

Black

Red

White

This corresponds to Option A.

Question142

At certain temperature, rod A and rod B of different materials have lengths $\mathrm{L_A}$ and $\mathrm{L_B}$ respectively. Their coefficients of linear expansion are α_A and α_B respectively. It is observed that the difference between their lengths remains constant at all temperatures. The ratio $\mathrm{L_A} : \mathrm{L_B}$ is given by

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Options:

A. $\frac{\alpha_A}{\alpha_B}$

B. $\frac{\alpha_B}{\alpha_A}$

C. $\frac{\alpha_A+\alpha_B}{\alpha_A}$

D. $\frac{\alpha_A+\alpha_B}{\alpha_B}$

Answer: B

Solution:

To find the ratio $L_A : L_B$ such that the difference in lengths of rods A and B remains constant at all temperatures, we start by considering their lengths at a temperature t.

The length of rod A at temperature t is given by:

$$L_{A_t} = L_A + L_A\alpha_A\Delta t$$

Similarly, the length of rod B at temperature t is:

$L_{B_t} = L_B + L_B \alpha_B \Delta t$

The difference in their lengths at temperature t is then:

$\Delta L = L_{A_t} - L_{B_t} = (L_A - L_B) + (L_A \alpha_A - L_B \alpha_B) \Delta t$

For this difference to remain constant regardless of changes in temperature, the coefficient of Δt must be zero:

$L_A \alpha_A - L_B \alpha_B = 0$

Thus, we have:

$L_A \alpha_A = L_B \alpha_B$

Rearranging to find the length ratio:

$\frac{L_A}{L_B} = \frac{\alpha_B}{\alpha_A}$

This relationship tells us that the ratio of lengths $L_A : L_B$ is $\frac{\alpha_B}{\alpha_A}$.

Question143

The internal energy of a gas will increase when it

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Options:

A. expands adiabatically.

B. is compressed adiabatically.

C. expands isothermally.

D. is compressed isothermally.

Answer: B

Solution:

The internal energy of a gas will increase when it is subjected to an adiabatic process in which work is done on the gas. This is because, in an adiabatic process, no heat is exchanged with the surroundings, so any work done on the gas results in a change in its internal energy.

Explanation

Adiabatic Process: A process in which no heat is transferred to or from the system. The change in internal energy is solely due to the work done on or by the system.

Compression vs. Expansion:

In **adiabatic compression**, work is done on the gas, which increases its internal energy. This results in a rise in temperature.

In **adiabatic expansion**, the gas does work on the surroundings, causing a decrease in its internal energy, thus leading to a drop in temperature.

Isothermal Process: A process that occurs at constant temperature. For an ideal gas, the internal energy depends only on temperature, hence there is no change in internal energy.

In **isothermal compression** or **isothermal expansion**, although work is done, the heat exchanged is such that the internal energy remains constant.

Therefore, the correct option is:

Option B: The internal energy of a gas will increase when it is compressed adiabatically.

Question144

A gas is contained in closed vessel. The initial temperature of the gas is $100^{\circ}\mathrm{C}$. If the pressure of the gas is increased by 4%, the increase in the temperature of the gas is

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Options:

A. $2^{\circ}\mathrm{C}$

B. $3^{\circ}\mathrm{C}$

C. $4^{\circ}\mathrm{C}$

D. $5^{\circ}\mathrm{C}$

Answer: A

Solution:

To find the increase in the temperature of the gas, we start with the initial conditions and apply the principles of ideal gas law. The initial pressure is given as P_1, and the pressure increase is 4%, so the new pressure is:

$P_2 = P_1 + 0.04P_1 = 1.04P_1$

Using the ideal gas equation $PV = nRT$, we relate the initial and final states as follows, assuming the volume and the amount of gas remain constant:

$\frac{T_1}{T_2} = \frac{P_1}{P_2}$

The initial temperature T_1 is given as $100^\circ\mathrm{C}$, which converts to Kelvin as $373\,\mathrm{K}$.

Supposing the final temperature is $T_2 = T_1 + \Delta T$:

$\frac{373}{373+\Delta T} = \frac{1}{1.04}$

By cross-multiplying, we solve for ΔT:

$373(1.04) = 373 + \Delta T$

$387.92 = 373 + \Delta T$

$\Delta T = 387.92 - 373 = 14.92\,\mathrm{K}$

Since temperature changes in Celsius and Kelvin are equivalent:

$\Delta T = 14.92^\circ\mathrm{C}$

Thus, the increase in the temperature of the gas is $14.92^\circ\mathrm{C}$.

Question145

For an ideal gas, in an isobaric process, the ratio of heat supplied ' Q ' to the work done ' w ' by the system is ($\gamma =$ ratio of specific heat at constant pressure to that at constant volume)

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Options:

A. $\frac{1}{\gamma}$

B. $\frac{1}{\gamma-1}$

C. $\frac{\gamma}{\gamma-1}$

D. $\frac{\gamma-1}{\gamma}$

Answer: C

Solution:

In an isobaric process (constant pressure), the relationship between the heat supplied (Q) and the work done (w) by an ideal gas can be analyzed using the first law of thermodynamics and the specific heats.

The first law of thermodynamics states:

$$Q = \Delta U + w$$

For an ideal gas, the change in internal energy (ΔU) is given by:

$$\Delta U = nC_v \Delta T$$

where C_v is the specific heat at constant volume.

The work done (w) during an isobaric process is:

$$w = P\Delta V = nR\Delta T$$

where R is the ideal gas constant.

In an isobaric process, the heat supplied (Q) can be expressed using the specific heat at constant pressure (C_p):

$$Q = nC_p \Delta T$$

The ratio of specific heats is defined as:

$$\gamma = \frac{C_p}{C_v}$$

Using the expression for Q and rearranging, we can find the ratio $\frac{Q}{w}$:

$$\frac{Q}{w} = \frac{nC_p \Delta T}{nR\Delta T} = \frac{C_p}{R}$$

From the definition of γ, we can write:

$$C_p = \gamma C_v$$

And from the relationship $C_p - C_v = R$, we have:

$$C_p = \frac{\gamma R}{\gamma - 1}$$

Thus, the ratio of heat supplied to work done becomes:

$$\frac{Q}{w} = \frac{C_p}{R} = \frac{\gamma R}{(\gamma - 1)R} = \frac{\gamma}{\gamma - 1}$$

Therefore, the correct option is:

Option C

$$\frac{\gamma}{\gamma - 1}$$

Question146

The temperature of a gas is $-80^{\circ}\mathrm{C}$. To what temperature the gas should be heated so that the r.m.s. speed is increased by 2 times?

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Options:

A. $499^{\circ}\mathrm{C}$

B. $772^{\circ}\mathrm{C}$

C. $1464^{\circ}\mathrm{C}$

D. $1737^{\circ}\mathrm{C}$

Answer: A

Solution:

To solve the problem, we begin by converting the initial temperature from Celsius to Kelvin:

$T_1 = -80^{\circ}\mathrm{C} = -80 + 273\,\mathrm{K} = 193\,\mathrm{K}$

The root mean square (RMS) velocity (v_{rms}) of a gas is proportional to the square root of its temperature, T:

$v_{\mathrm{rms}} \propto \sqrt{T}$

When the speed is increased by two times, the final speed becomes:

$(2\,v_{\mathrm{rms}})_1$

This implies:

$\frac{(v_{\mathrm{rms}})_2}{(v_{\mathrm{rms}})_1} = \sqrt{\frac{T_2}{T_1}} = 2$

Therefore, the relationship between the initial and final temperatures is:

$\frac{T_2}{T_1} = 4$

Solving for T_2:

$T_2 = 4 \times 193\,\mathrm{K} = 772\,\mathrm{K}$

Converting back to Celsius, we subtract 273:

$T_2 = 772\,\mathrm{K} - 273 = 499^{\circ}\mathrm{C}$

Thus, the gas should be heated to 499°C to double the RMS speed.

Question147

Two bodies ' X ' and ' Y ' at temperatures ' T_1 ' K and ' T_2 ' K respectively have the same dimensions. If their emissive powers are same, the relation between their temperatures is

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Options:

A. $\frac{T_1}{T_2}=\frac{1}{3}$

B. $\frac{\mathrm{T}_1}{\mathrm{~T}_2}=\frac{81}{1}$

C. $\frac{\mathrm{T}_1}{\mathrm{~T}_2}=\frac{3^{\frac{1}{4}}}{1}$

D. $\frac{T_1}{T_2}=\frac{9^{\frac{1}{4}}}{1}$

Answer: A

Solution:

According to Stefan-Boltzmann's law, the emissive power of a body is given by:

$\frac{dQ}{dt}=e\left(\sigma A T^4\right)$ ..... (i)

Here, dQ/dt represents the rate of emission of radiant energy, e is the emissivity, σ is the Stefan-Boltzmann constant, A is the surface area, and T is the temperature in Kelvin.

Given that the dimensions of the two bodies, X and Y, are identical:

$A_1=A_2$ ..... (ii)

It is also stated that the emissive powers of both bodies are the same. Therefore, we have:

$$\frac{dQ_1}{dt}=\frac{dQ_2}{dt}$$

$\Rightarrow e_1 T_1^4=e_2 T_2^4$ ... [From equations (i) and (ii)]

$\Rightarrow\left(\frac{T_1}{T_2}\right)^4=\frac{e_2}{e_1}$

This equation describes the relationship between the temperatures T_1 and T_2 of the two bodies, given their equal emissive powers.

Question148

A lead bullet moving with velocity ' v ' strikes a wall and stops. If 50% of its energy is converted into heat, then the increase in temperature is ($s =$ specific heat of lead)

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Options:

A. $\frac{\mathrm{v}^2 \mathrm{~s}}{2 \mathrm{~J}}$

B. $\frac{v^2}{4 \mathrm{Js}}$

C. $\frac{\mathrm{v}^2 \mathrm{~s}}{\mathrm{~J}}$

D. $\frac{2 v^2}{\mathrm{Js}}$

Answer: B

Solution:

To determine the increase in temperature when a lead bullet moving with velocity v strikes a wall and stops, given that 50% of its energy is converted into heat, follow these calculations:

Initial Kinetic Energy (K.E.) of the Bullet:

$\text{K.E.} = \frac{1}{2} m v^2$

Energy Converted to Heat:

$\text{Energy converted to heat} = 50\% \text{ of K.E.} = \frac{1}{2} \times \frac{1}{2} m v^2 = \frac{1}{4} m v^2$

Heat Absorbed by the Bullet:

Let ΔT be the increase in temperature, s the specific heat capacity of lead, and m the mass. Then the heat absorbed Q is:

$Q = m s \Delta T$

Equating Mechanical Energy to Thermal Energy:

Using the formula for the mechanical equivalent of heat J:

$$J = \frac{\text{Work}}{\text{Heat}} = \frac{\frac{1}{4}mv^2}{ms\Delta T}$$

Solving for Increase in Temperature:

Rearrange to find ΔT:

$$\Delta T = \frac{v^2}{4Js}$$

Thus, the increase in temperature ΔT of the bullet is expressed as $\frac{v^2}{4Js}$.

Question149

If C_p and C_v are molar specific heats of an ideal gas at constant pressure and volume respectively and ' γ ' is $\mathrm{C_p/C_v}$ then $\mathrm{C_p}$ =(R = universal gas constant)

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Options:

A. $\frac{\gamma \mathrm{R}}{\gamma-1}$

B. $\gamma \mathrm{R}$

C. $\frac{1+\gamma}{1-\gamma}$

D. $\frac{\mathrm{R}}{\gamma-1}$

Answer: A

Solution:

To understand how to derive the expression for C_p, the molar specific heat of an ideal gas at constant pressure, let's go through the following steps:

We start with the given relation for the heat capacity ratio (also known as the adiabatic index), γ, which is defined as:

$$\gamma = \frac{C_p}{C_v}$$

This implies:

$\frac{C_v}{C_p}=\frac{1}{\gamma}$

We can express the difference in specific heats as:

$\frac{C_v-C_p}{C_p}=\frac{1-\gamma}{\gamma}$

Rearranging the terms gives:

$\frac{-(C_p-C_v)}{C_p}=\frac{1-\gamma}{\gamma}$

Since the relation between the specific heats is $C_p-C_v=R$ (where R is the universal gas constant), we substitute this into the equation:

$\frac{-R}{C_p}=\frac{1-\gamma}{\gamma}$

Simplifying, we have:

$\frac{R}{C_p}=\frac{\gamma-1}{\gamma}$

Finally, solving for C_p, we find:

$C_p=\frac{\gamma R}{\gamma-1}$

Thus, the molar specific heat at constant pressure C_p for an ideal gas is given by the expression $\frac{\gamma R}{\gamma-1}$.

Question150

The change in the internal energy of the mass of gas, when the volume changes from ' V ' to ' 2 V ' at constant pressure ' P ' is (γ is the ratio of specific heat of gas at constant pressure to specific heat at constant volume)

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Options:

A. $\frac{\mathrm{PV}}{\gamma-1}$

B. $\frac{\mathrm{PV}}{\gamma+1}$

C. $\frac{\gamma-1}{\mathrm{PV}}$

D. $\frac{\gamma+1}{\mathrm{PV}}$

Answer: A

Solution:

The change in the internal energy, ΔU, of a gas when its volume changes from 'V' to '2V' at constant pressure 'P' can be determined using the following derivation.

The formula for the change in internal energy is given by:

$\Delta U = nC_V\Delta T$ .... (i)

We are given that the ratio of specific heats is:

$\frac{C_P}{C_V} = \gamma$

and the relation between them is:

$C_P - C_V = R$

This leads to:

$1 + \frac{R}{C_V} = \gamma$

From this, we derive:

$C_V = \frac{R}{\gamma-1}$

Substitute C_V into equation (i):

$\Delta U = n\left(\frac{R}{\gamma-1}\right)\Delta T$

Under constant pressure, we use the equation:

$P\Delta V = nR\Delta T$

Thus, substituting for ΔT from above:

$\Delta U = \frac{P\Delta V}{\gamma-1} = \frac{P(2V-V)}{\gamma-1} = \frac{PV}{\gamma-1}$

This indicates that the change in internal energy is $\frac{PV}{\gamma-1}$.

Question151

A pergect gas of volume 5 litre is compressed isothermally to volume of 1 litre. The r.m.s. speed of the molecules will

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Options:

A. increase by 10 times

B. decrease by 10 times

C. increase by 5 times

D. remain unchanged

Answer: D

Solution:

When a perfect gas of volume 5 liters is compressed isothermally to a volume of 1 liter, the root mean square (r.m.s.) speed of the gas molecules does not change.

This is because the compression is isothermal, meaning the temperature remains constant throughout the process. The r.m.s. speed of gas molecules is determined by the formula:

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

Where:

R is the universal gas constant,

T is the absolute temperature, and

M is the molar mass of the gas.

Since the temperature T is unchanged during an isothermal process, the r.m.s. speed v_{rms} remains the same. Thus, there is no impact on the r.m.s. speed due to the reduction in volume given that the temperature is constant.

Question152

A real gas behaves as an ideal gas at

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Options:

A. low pressure and low temperature.

B. low pressure and high temperature.

C. high pressure and low temperature.

D. high pressure and high temperature.

Answer: B

Solution:

A real gas tends to behave approximately like an ideal gas when its molecules are far apart (i.e., **low pressure**) and their thermal energy is relatively high (i.e., **high temperature**). Under these conditions, intermolecular forces become negligible and the gas can be approximated as ideal.

Hence, the correct choice is :

(B) low pressure and high temperature.

Question153

According to the law of equipartition of energy the molar specific heat of a diatomic gas at constant volume where the molecule has one additional vibrational mode is

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Options:

A. $\frac{9}{2}\mathrm{R}$

B. $\frac{5}{2}R$

C. $\frac{3}{2}R$

D. $\frac{7}{2}R$

Answer: D

Solution:

The law of equipartition of energy states that each quadratic degree of freedom contributes $\frac{1}{2}R$ per mole to the internal energy, where R is the gas constant.

For a diatomic molecule with one additional vibrational mode, we count the degrees of freedom as follows:

Translational Motion:

3 degrees of freedom

Contribution: $3 \times \frac{1}{2} R = \frac{3}{2} R$

Rotational Motion:

Diatomic molecules have 2 rotational degrees of freedom (rotation about the two axes perpendicular to the bond)

Contribution: $2 \times \frac{1}{2} R = R$

Vibrational Mode:

A vibrational mode contributes 2 degrees of freedom (one for kinetic energy and one for potential energy)

Contribution: $2 \times \frac{1}{2} R = R$

Now, we simply add these contributions:

$C_v = \frac{3}{2} R + R + R = \frac{7}{2} R.$

Thus, the molar specific heat of the diatomic gas at constant volume, with one additional vibrational mode, is:

Option D: $\frac{7}{2} R.$

Question154

A carnot engine, whose efficiency is 40% takes heat from a source maintained at temperature 600 K . It is desired to have an efficiency 60%, then the intake temperature for the same exhaust (sink) temperature should be

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Options:

A. 1800 K

B. 1200 K

C. 900 K

D. 600 K

Answer: C

Solution:

To find the required intake temperature for a Carnot engine with increased efficiency, we can use the formula for the efficiency (η) of a Carnot engine:

$\eta=1-\frac{T_{\mathrm{L}}}{T_{\mathrm{H}}}$

Initially, the given efficiency is 40%, and the source temperature (T_{H}) is 600 K. We need to determine the sink temperature (T_{L}):

$\frac{40}{100}=1-\frac{T_{\mathrm{L}}}{600}$

Solving for T_{L}:

$\frac{T_{\mathrm{L}}}{600}=\frac{60}{100}$

$T_{\mathrm{L}}=360 \mathrm{~K}$

Now, for the desired efficiency of 60%, we use:

$\frac{60}{100}=1-\frac{360}{T_{\mathrm{H}}}$

Solving for the new intake temperature (T_{H}), we have:

$\frac{360}{T_{\mathrm{H}}}=\frac{40}{100}$

$T_{\mathrm{H}}=900 \mathrm{~K}$

Therefore, to achieve an efficiency of 60%, the intake temperature should be 900 K.

Question155

Two rods of same length \& material transfer a given amount of heat in 12 s when they are joined end to end. But when they are joined length wise parallel to each other they will transfer same amount of heat in same condition in time

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Options:

A. 24 s

B. 3 s

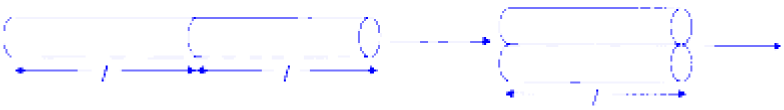
C. 1.5 s

D. 48 s

Answer: B

Solution:

Let the heat transferred be Q.



When rods are joined end to end, heat transferred by each rod

$= Q = \frac{KA\triangle\theta}{2} \times 12 \quad ...$ (i)

When rods are joined lengthwise,

$Q = \frac{K2\ A\Delta\theta}{l}t \quad ...$ (ii)

From equation (i) and (ii),

$$\frac{K2\ A\Delta\theta}{l}t = \frac{KA\Delta\theta}{2l} \times 12$$
$$\therefore \quad t = \frac{12}{2 \times 2} = 3\ s$$

Question156

An insulated container contains a monoatomic gas of molar mass ' m '. The container is moving with velocity ' V '. If it is stopped suddenly, the change in temperature is ($R =$ gas constant)

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Options:

A. $\frac{mV^2}{5R}$

B. $\frac{mV^2}{3R}$

C. $\frac{mV^2}{7R}$

D. $\frac{mV^2}{9R}$

Answer: B

Solution:

When the insulated container, which contains a monoatomic gas with molar mass ' m ', is suddenly stopped from moving at velocity ' V ', there is a change in temperature due to the conversion of kinetic energy into internal energy.

The loss in kinetic energy of the gas is:

$\frac{1}{2}(\mathrm{mn})V^2$

where n is the number of moles of the gas.

For a monoatomic gas, the change in internal energy is given by:

$\Delta \mathrm{U}=\frac{3}{2} \mathrm{nR} \Delta \mathrm{T}$

The change in kinetic energy is entirely converted into internal energy, leading to:

$\frac{3}{2} n R \Delta T=\frac{1}{2} m n V^2$

Solving for the change in temperature, ΔT, we have:

$\Delta T=\frac{m V^2}{3 R}$

This equation shows the direct relationship between the change in temperature and the initial velocity of the container, illustrating how kinetic energy influences the internal energy and hence the temperature change in an ideal gaseous system.

Question157

In an isobaric process of an ideal gas, the ratio of work done by the system to the heat supplied $\left(\frac{W}{Q}\right)$ is

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Options:

A. $\frac{1}{\gamma-1}$

B. γ

C. $\frac{\gamma}{\gamma-1}$

D. $\frac{\gamma-1}{\gamma}$

Answer: D

Solution:

For an isobaric process involving an ideal gas, we need to find the ratio of the work done by the system to the heat supplied, denoted as $\frac{W}{Q}$.

In an isobaric process:

The heat supplied to the system is given by:

$\Delta Q = nC_p\Delta T$

where n is the number of moles, C_p is the specific heat at constant pressure, and ΔT is the change in temperature.

The change in internal energy is:

$\Delta U = nC_v\Delta T$

where C_v is the specific heat at constant volume.

The work done by the system is:

$W = \Delta Q - \Delta U = nC_p\Delta T - nC_v\Delta T$

To find the ratio $\frac{W}{\Delta Q}$:

$$\begin{aligned}\frac{W}{\Delta Q} &= \frac{nC_p\Delta T - nC_v\Delta T}{nC_p\Delta T}\\ &= \frac{C_p - C_v}{C_p}\\ &= \frac{\frac{C_p}{C_v} - 1}{\frac{C_p}{C_v}}\end{aligned}$$

Since the ratio $\frac{C_p}{C_v} = \gamma$, where γ is the heat capacity ratio, we have:

$\frac{W}{\Delta Q} = \frac{\gamma-1}{\gamma}$

This concludes the derivation, showing that the ratio of work done by the system to the heat supplied in an isobaric process is $\frac{\gamma-1}{\gamma}$.

Question158

A sphere is at temperature 600 K . In an external environment of 200 K , its cooling rate is ' R ' When the temperature of the sphere falls to 400 K , then cooling rate ' R ' will become

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Options:

A. $\frac{3}{16}$R

B. $\frac{9}{16} R$

C. $\frac{16}{9} R$

D. $\frac{16}{3} R$

Answer: A

Solution:

The rate of energy emission from a hot surface is described by the Stefan-Boltzmann Law, which can be expressed as:

$R=e \sigma A\left(T^4-T_0^4\right)$

In this formula:

R is the cooling rate,

e is the emissivity of the surface,

σ is the Stefan-Boltzmann constant,

A is the surface area of the sphere,

T is the temperature of the sphere,

T_0 is the temperature of the surrounding environment.

To determine the new cooling rate R' when the sphere's temperature decreases from 600 K to 400 K, we use the ratio:

$\frac{R'}{R}=\frac{\left(400^4-200^4\right)}{\left(600^4-200^4\right)}$

Calculating further:

$\frac{R'}{R}=\frac{(256-16) \times 10^8}{(1296-16) \times 10^8}=\frac{240 \times 10^8}{1280 \times 10^8}=\frac{3}{16}$

Thus, the new cooling rate is:

$R' = \frac{3}{16} R$

Question159

A gas expands in such a way that its pressure and volume satisfy the condition $\mathrm{PV}^2 =$ constant. Then the temperature of the gas

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Options:

A. will decrease.

B. will increase.

C. will not change.

D. may increase or decrease depending upon the values of pressure and volume.

Answer: A

Solution:

To analyze how the temperature of a gas changes during expansion, given that the pressure P and volume V satisfy the condition $\mathrm{PV}^2 =$ constant, we start with the ideal gas equation:

$\mathrm{PV} = \mathrm{nRT}$

Using the given condition:

$\mathrm{PV}^2 = \text{constant}$

From the ideal gas equation, we can express P as:

$P = \frac{nRT}{V}$

Substituting this into the given condition:

$\left(\frac{nRT}{V}\right) V^2 = \text{constant}$

This simplifies to:

$nRT \cdot V = \text{constant}$

Therefore, we find that:

$TV =$ constant

From this relationship, we observe that:

$T \propto \frac{1}{V}$

Thus, if the gas expands (meaning V increases), the temperature T must decrease to maintain the equation $TV =$ constant. Therefore, during expansion under this condition, the temperature of the gas decreases.

Question160

The r.m.s. velocity of gas molecules kept at temperature $27^{\circ}\mathrm{C}$ in a vessel is $61 \mathrm{~m} / \mathrm{s}$. Molecular weight of gas is nearly

$$\left[\mathrm{R}=8.31 \frac{\mathrm{J}}{\mathrm{mol~K}}\right]$$

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Options:

A. 2

B. 4

C. 28

D. 32

Answer: A

Solution:

The root mean square (r.m.s.) velocity of gas molecules is given by the equation:

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

where v_{rms} is the r.m.s. velocity, R is the universal gas constant, T is the temperature in Kelvin, and M is the molar mass of the gas in kg/mol.

Given:

$v_{\text{rms}} = 61$ m/s

$T = 27^{\circ}\mathrm{C} = 27 + 273 = 300$ K

$R = 8.31$ J/(mol \cdot K)

To find the molar mass M, rearrange the equation:

$M = \frac{3RT}{v_{\text{rms}}^2}$

Substitute the given values into the equation:

$M = \frac{3 \times 8.31 \text{ J/(mol} \quad \cdot\text{K)} \ \times 300 \text{ K}}{(61 \text{ m/s} \ )^2}$

Calculating:

Square the velocity:

$61^2 = 3721 \text{ m}^2/\text{s}^2$

Multiply the constants:

$3 \times 8.31 \times 300 = 7479$ J/mol

Find M:

$M = \frac{7479}{3721}$ kg/mol

Calculate the value:

$M \approx 2.0105$ kg/mol

Since the molecular weight should be expressed in terms of grams per mole for standard usage:

$M \approx 2.0105 \times 1000 \text{ g/mol} = 2.0105 \text{ g/mol}$

Therefore, the molecular weight of the gas is nearly 2. The correct option is:

Option A: 2

Question161

A diatomic gas undergoes adiabatic change. Its pressure P and temperature T are related as $\mathrm{P} \propto \mathrm{T}^{\mathrm{x}}$ where the value of x is

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Options:

A. 3.5

B. 2.5

C. 4.5

D. 3

Answer: A

Solution:

For a diatomic gas undergoing an adiabatic process, the relationship between pressure (P) and temperature (T) can be derived using the adiabatic condition and the gas law.

The adiabatic condition for an ideal gas is given by:

$PV^{\gamma} = \text{constant}$

where P is pressure, V is volume, and γ (gamma) is the adiabatic index or heat capacity ratio given by:

$\gamma = \frac{C_p}{C_v}$

For a diatomic gas, the degrees of freedom f are 5, so:

$C_v = \frac{f}{2}R = \frac{5}{2}R$

$C_p = C_v + R = \frac{7}{2}R$

Thus,

$\gamma = \frac{C_p}{C_v} = \frac{\frac{7}{2}R}{\frac{5}{2}R} = \frac{7}{5}$

The ideal gas law is given by:

$PV = nRT$

During an adiabatic process, we also have:

$P \propto V^{-\gamma}$

and

$T \propto V^{\gamma-1}$

Substituting the relationship for temperature:

From the ideal gas law $PV = nRT$, we have $P = \frac{nRT}{V}$.

We can substitute $T \propto V^{\gamma-1}$ into the ideal gas law:

$P \propto \left(V^{\gamma-1}\right)^{\frac{1}{V}} \Rightarrow P \propto \left(V^{1-\gamma}\right)$

Hence, $P \propto T^{\frac{\gamma}{\gamma-1}}$.

Plugging in the value of γ for a diatomic gas:

$\gamma = \frac{7}{5}$

$\frac{\gamma}{\gamma-1} = \frac{\frac{7}{5}}{\frac{7}{5}-1} = \frac{\frac{7}{5}}{\frac{2}{5}} = \frac{7}{2}$

Thus, for a diatomic gas, the relationship is:

$P \propto T^{\frac{7}{2}}$

Therefore, the value of x is 3.5.

Answer: Option A, $x = 3.5$.

Question162

A monoatomic gas is heated at constant pressure. The percentage of total heat used for doing external work is

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Options:

A. 30%

B. 40%

C. 50%

D. 60%

Answer: B

Solution:

For a monoatomic gas, when heated at constant pressure, the heat added to the system can be used to do work and to change the internal energy.

The specific heat at constant pressure is related to the specific heat at constant volume by:

$C_p = C_v + R$

where R is the ideal gas constant. For a monoatomic gas, $C_v = \frac{3}{2}R$, so:

$C_p = \frac{3}{2}R + R = \frac{5}{2}R$

The work done by the gas during expansion at constant pressure can be represented by:

$W = P\Delta V = nR\Delta T$

The total heat supplied at constant pressure is:

$Q = nC_p \Delta T = n\left(\frac{5}{2}R\right)\Delta T$

The percentage of heat used to do work is given by the ratio:

Percentage of heat used for work $= \frac{W}{Q} \times 100 = \frac{nR\Delta T}{n\left(\frac{5}{2}R\right)\Delta T} \times 100$

This simplifies to:

$\frac{2}{5} \times 100 = 40\%$

Thus, the percentage of total heat used for doing external work is **40%**.

Option B (40%) is the correct answer.

Question163

Two rods, one of copper (Cu) and the other of iron (Fe) having initial lengths L_1 and L_2 respectively are connected together to form a single rod of length $L_1 + L_2$. The coefficient of linear expansion of Cu and Fe are α_c and α_i respectively. If the length of each rod increases by the same amount when their temperatures are raised by $t^{\circ}\mathrm{C}$, then ratio of $\frac{L_1 - L_2}{L_1 + L_2}$ will be

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Options:

A. $\frac{\alpha_i}{\alpha_c + \alpha_i}$

B. $\frac{\alpha_c}{\alpha_c + \alpha_i}$

C. $\frac{\alpha_i - \alpha_c}{\alpha_c + \alpha_i}$

D. $\frac{\alpha_c - \alpha_i}{\alpha_c + \alpha_i}$

Answer: C

Solution:

When two rods of different materials are connected and increase by the same amount in length due to temperature change, the expansion can be described as follows:

The change in length for the copper rod is given by:

$$\Delta L_1 = L_1 \alpha_c t$$

The change in length for the iron rod is:

$$\Delta L_2 = L_2 \alpha_i t$$

Given that these changes in lengths are equal:

$$L_1 \alpha_c t = L_2 \alpha_i t$$

By simplifying, we have:

$$L_1 \alpha_c = L_2 \alpha_i$$

From this, we can write:

$$\frac{L_1}{L_2} = \frac{\alpha_i}{\alpha_c}$$

We need to find the ratio:

$$\frac{L_1 - L_2}{L_1 + L_2}$$

Start by expressing L_1 and L_2 in terms of a common variable:

Let $L_2 = x$, then $L_1 = \frac{\alpha_i}{\alpha_c} x$.

Substitute these into $\frac{L_1 - L_2}{L_1 + L_2}$:

$$= \frac{\frac{\alpha_i}{\alpha_c} x - x}{\frac{\alpha_i}{\alpha_c} x + x}$$

Factor out x from the numerator and the denominator:

$$= \frac{x\left(\frac{\alpha_i}{\alpha_c} - 1\right)}{x\left(\frac{\alpha_i}{\alpha_c} + 1\right)}$$

Cancel out x:

$$= \frac{\frac{\alpha_i - \alpha_c}{\alpha_c}}{\frac{\alpha_i + \alpha_c}{\alpha_c}}$$

Simplify further:

$$= \frac{\alpha_i - \alpha_c}{\alpha_i + \alpha_c}$$

Thus, the correct ratio is:

Option C

$$\frac{\alpha_i - \alpha_c}{\alpha_c + \alpha_i}$$

Question164

The specific heat of argon at constant pressure and constant volume are C_p and C_v respectively. It's density ' ρ ' at N.T.P. will be [P and T are pressure and temperature respectively at N.T.P.]

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Options:

A. $\frac{P}{T(C_p-C_v)}$

B. $\frac{\mathrm{PT}}{(\mathrm{C_p}-\mathrm{C_v})}$

C. $\frac{T(C_p-C_v)}{P}$

D. $\frac{(\mathrm{C_p}-\mathrm{C_v})}{\mathrm{PT}}$

Answer: A

Solution:

The density of a gas can be related to its pressure, temperature, and specific heat capacities through the ideal gas laws and the relation between specific heat capacities.

For an ideal gas, the relation between the specific heat capacities is given by:

$C_p - C_v = R$

where R is the universal gas constant. For argon at Normal Temperature and Pressure (N.T.P.), using the ideal gas equation:

$PV = nRT$

where:

P is the pressure,

V is the volume,

n is the number of moles,

R is the gas constant,

T is the temperature.

The molar mass M and the number of moles n are related to the density ρ as follows:

$\rho=\frac{m}{V}=\frac{nM}{V}=\frac{PM}{RT}$

Since we're interested in the density ρ at N.T.P., we use the relation:

$\rho=\frac{P}{T\frac{R}{M}}=\frac{P}{T\frac{C_p-C_v}{M}}$

which simplifies to:

$\rho=\frac{P}{T(C_p-C_v)}$

Therefore, the correct option for the density of argon at N.T.P. in terms of the specific heat capacities is:

Option A:

$\frac{P}{T(C_p-C_v)}$

Question165

The r.m.s. velocity of hydrogen at S.T.P. is ' u ' $\mathrm{m/s}$. If the gas is heated at constant pressure till its volume becomes three times, then the final temperature of the gas and the r.m.s. speed are respectively

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Options:

A. $819\ \mathrm{K},(\sqrt{3})\mathrm{um/s}$

B. $1092\ \mathrm{K}, 3\mathrm{um/s}$

C. $819\ \mathrm{K}, \frac{\mathrm{u}}{\sqrt{3}}\ \mathrm{m/s}$

D. $1092\ \mathrm{K}, \frac{\mathrm{u}}{3}\ \mathrm{m/s}$

Answer: A

Solution:

To determine the final temperature and the root mean square (r.m.s.) velocity of the hydrogen gas when its volume becomes three times at constant pressure, the following relationships and concepts are used:

Ideal Gas Law at Constant Pressure:

At constant pressure, the volume (V) of an ideal gas varies directly with its absolute temperature (T):

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Given that the volume triples ($V_2 = 3V_1$), and initially, the gas is at Standard Temperature and Pressure (STP) where $T_1 = 273$ K, we can solve for the final temperature T_2:

$\frac{V_1}{273} = \frac{3V_1}{T_2}$

Simplifying gives:

$T_2 = 819\,\mathrm{K}$

RMS Velocity Calculation:

The r.m.s. velocity of a gas is given by:

$u = \sqrt{\frac{3kT}{m}}$

where k is the Boltzmann constant and m is the molecular mass. The r.m.s. velocity is proportional to the square root of the temperature ($u \propto \sqrt{T}$).

Initially, the velocity $u_1 = u$ at $T_1 = 273$ K. For the final velocity u_2 at $T_2 = 819$ K:

$u_2 = u\sqrt{\frac{T_2}{T_1}} = u\sqrt{\frac{819}{273}} = u\sqrt{3}$

Thus, the final temperature of the gas is $819\,\mathrm{K}$ and the final r.m.s. speed is $u\sqrt{3}\,\mathrm{m/s}$.

The correct option is **Option A:** $819\,\mathrm{K},\ u\sqrt{3}\,\mathrm{m/s}$.

Question166

There are two samples A and B of a certain gas, which are initially at the same temperature and pressure. Both are compressed from volume v to $\frac{\mathrm{v}}{2}$. Sample A is compressed isothermally while sample B is compressed adiabatically. The final pressure of A is

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Options:

A. twice that of B.

B. equal to that of B.

C. more than that of B.

D. less than that of B .

Answer: D

Solution:

For an isothermal process.

$P_1 V_1 = P_2 V_2$

Given that $V_2 = \frac{V_1}{2}$. It can be clearly understood that for P_2 V_2 to remain constant,

$P_2 = 2P_1$ .... (i).

For an adiabatic process, $PV^\gamma =$ constant.

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

γ is always greater than 1. From equations (i) and (ii), it can be seen that the pressure change in an adiabatic process would be greater than that in an isothermal process for the same change in volume.

Question167

Two rods, one of aluminium and the other of steel, having initial lengths ' L_1 ' and ' L_2 ' are connected together to form a single rod of length $(L_1 + L_2)$. The coefficients of linear expansion of aluminium and steel are ' α_1 ' and ' α_2 ' respectively. If the length of each rod increases by the same amount, when their temperatures are raised by $t^{L}C$, then the ratio $\frac{L_1}{L_1+L_2}$ will be

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Options:

A. $\frac{\alpha_2}{\alpha_1}$

B. $\frac{\alpha_1}{\alpha_2}$

C. $\frac{\alpha_2}{\alpha_1+\alpha_2}$

D. $\frac{\alpha_1}{\alpha_1-\alpha_2}$

Answer: C

Solution:

When the two rods, one made of aluminum and the other made of steel, are subjected to the same temperature increase, the length of each rod increases by the same amount. This implies:

For aluminum: $\Delta L_{\text{aluminum}} = L_1 \alpha_1 t$

For steel: $\Delta L_{\text{steel}} = L_2 \alpha_2 t$

Given that these increases in lengths are equal, so:

$L_1 \alpha_1 t = L_2 \alpha_2 t$

Cancelling the common factor t from both sides gives:

$L_1 \alpha_1 = L_2 \alpha_2$

We need to find the ratio $\frac{L_1}{L_1+L_2}$.

From $L_1 \alpha_1 = L_2 \alpha_2$, we can express L_2 in terms of L_1:

$L_2 = \frac{L_1 \alpha_1}{\alpha_2}$

Substituting this into $L_1 + L_2$:

$L_1 + L_2 = L_1 + \frac{L_1 \alpha_1}{\alpha_2} = L_1\left(1 + \frac{\alpha_1}{\alpha_2}\right)$

Therefore, the desired ratio is:

$\frac{L_1}{L_1+L_2} = \frac{L_1}{L_1\left(1+\frac{\alpha_1}{\alpha_2}\right)}$

Simplifying:

$\frac{L_1}{L_1\left(1+\frac{\alpha_1}{\alpha_2}\right)} = \frac{1}{1+\frac{\alpha_1}{\alpha_2}} = \frac{\alpha_2}{\alpha_1+\alpha_2}$

So the correct option is:

Option C: $\frac{\alpha_2}{\alpha_1+\alpha_2}$.

Question168

Given that ' x ' joule of heat is incident on a body. Out of that, total heat reflected and transmitted is ' y ' joule. The absorption coefficient of body is

Options:

A. $\frac{x}{y}$

B. $\frac{y}{x}$

C. $\frac{x-y}{x}$

D. $\frac{y-x}{x}$

Answer: C

Solution:

The absorption coefficient of a body, denoted by a, is a measure of the amount of incident heat that is absorbed by the body. The absorption coefficient can be calculated using the formula:

$a = \frac{\text{absorbed heat}}{\text{incident heat}}$

Given that the incident heat is x joules and the heat reflected and transmitted is y joules, the heat absorbed by the body can be expressed as:

absorbed heat $= x - y$

This is because the total heat accounted for includes reflected, transmitted, and absorbed heat, and it must equal the incident heat. Therefore, the absorption coefficient is:

$a = \frac{x-y}{x}$

Thus, the correct option is:

Option C

$\frac{x-y}{x}$

Question169

A diatomic ideal gas is used in Carnot engine as a working substance. If during the adiabatic expansion part of the cycle, the volume of the gas increases from V to 32 V , the efficiency of the engine is

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Options:

A. 0.25

B. 0.50

C. 0.75

D. 0.90

Answer: C

Solution:

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

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

where T_C is the temperature of the cold reservoir and T_H is the temperature of the hot reservoir.

For adiabatic processes involving an ideal gas, the relationship between temperature and volume is described by:

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

where γ (gamma) is the heat capacity ratio C_p/C_v. For a diatomic gas, γ is approximately 1.4.

During an adiabatic expansion:

Volume changes from V to $32V$.

The temperatures at the initial and final volumes are related by:

$T_1 V^{\gamma-1} = T_2 (32V)^{\gamma-1}$

Simplifying,

$\frac{T_2}{T_1} = \left(\frac{1}{32}\right)^{\gamma-1}$

Substitute $\gamma = 1.4$:

$\frac{T_2}{T_1} = \left(\frac{1}{32}\right)^{0.4}$

Calculate:

$\left(\frac{1}{32}\right)^{0.4} \approx \frac{1}{4}$ or $T_2 = \frac{T_1}{4}$

Thus, in terms of Carnot efficiency:

$T_H = T_1$

$T_C = T_2 \approx \frac{T_1}{4}$

So,

$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{\frac{T_1}{4}}{T_1} = 1 - \frac{1}{4} = 0.75$

Thus, the efficiency of the Carnot engine is:

Option C: 0.75

Question170

Two spherical black bodies of radii ' R_1 ' and ' R_2 ' and with surface temperature ' T_1 ' and ' T_2 ' respectively radiate the same power. The ratio of ' R_1 ' to ' R_2 ' will be

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Options:

A. $\left(\frac{T_2}{T_1}\right)^4$

B. $\left(\frac{T_2}{T_1}\right)^2$

C. $\left(\frac{T_1}{T_2}\right)^4$

D. $\left(\frac{T_1}{T_2}\right)^2$

Answer: B

Solution:

The power radiated by a black body is given by Stefan-Boltzmann law:

$P = \sigma A T^4$

where:

σ is the Stefan-Boltzmann constant,

A is the surface area of the black body,

T is the absolute temperature.

For a spherical black body with radius R, the surface area A is $4\pi R^2$. Therefore, the power P radiated by a spherical black body can be written as:

$P = \sigma(4\pi R^2)T^4$

For two spherical black bodies with radii R_1 and R_2 and temperatures T_1 and T_2 respectively, radiating the same power, we have:

$\sigma(4\pi R_1^2)T_1^4 = \sigma(4\pi R_2^2)T_2^4$

Simplifying this equation:

$R_1^2 T_1^4 = R_2^2 T_2^4$

To find the ratio of R_1 to R_2, rearrange the above equation:

$\left(\frac{R_1}{R_2}\right)^2 = \frac{T_2^4}{T_1^4}$

Taking the square root of both sides:

$\frac{R_1}{R_2} = \left(\frac{T_2}{T_1}\right)^2$

Thus, the ratio of R_1 to R_2 is:

Option B: $\left(\frac{T_2}{T_1}\right)^2$

Question171

Rate of flow of heat through a cylindrical rod is ' H_1 '. The temperature at the ends of the rod are ' T_1 ' and ' T_2 '. If all the dimensions of the rod become double and the temperature difference remains the same, the rate of flow of heat becomes ' H_2 '. Then

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Options:

A. $\mathrm{H}_2 = 4\mathrm{H}_1$

B. $\mathrm{H}_2 = 2\mathrm{H}_1$

C. $H_2 = \frac{H_1}{2}$

D. $H_2 = \frac{H_1}{4}$

Answer: B

Solution:

Let l_1 be the initial length of the rod and r_1 be the radius of the rod. The initial rate of heat flow through the rod is given by:

$H_1 = \frac{kA_1(T_2 - T_1)}{l_1}$

When all dimensions of the rod are doubled, the rate of heat flow becomes:

$H_2 = \frac{kA_2(T_2 - T_1)}{l_2}$

The relationship between the rates can be expressed as:

$\frac{H_2}{H_1} = \frac{A_2}{A_1} \times \frac{l_1}{l_2}$

If the radius is doubled, $r_2 = 2r_1$, then the new cross-sectional area is $A_2 = 4A_1$. Additionally, the new length is $l_2 = 2l_1$.

Thus,

$\frac{H_2}{H_1} = 4 \times \frac{1}{2} = 2$

Therefore, the new rate of heat flow is:

$H_2 = 2H_1$

Question172

A fixed mass of gas at constant pressure occupies a volume ' V '. The gas undergoes a rise in temperature so that the r.m.s. velocity of the molecules is doubled. The new volume will be

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Options:

A. $\frac{V}{2}$

B. $\frac{V}{\sqrt{2}}$

C. 2 V

D. 4 V

Answer: D

Solution:

For a fixed mass of gas at constant pressure, the volume occupied is 'V'. When the temperature rises, the root mean square (r.m.s.) velocity of the gas molecules doubles.

The r.m.s. velocity V_{rms} is given by:

$$V_{rms} = \sqrt{\frac{3KT}{M}}$$

This implies:

$$V_{rms}^2 \propto T$$

Therefore, if the r.m.s. velocity of the molecules is doubled:

$$T_2 = 4T \quad ...(i)$$

At constant pressure, the volume of the gas is directly proportional to the temperature:

$$V \propto T$$

Thus, we have the relationship:

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Substituting the known values from equation (i):

$$\frac{V}{V_2} = \frac{T}{4T}$$

Solving for V_2:

$$V_2 = 4V$$

Question173

In an isobaric process

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Options:

A. pressure is constant.

B. volume is constant.

C. temperature is constant.

D. internal energy is constant.

Answer: A

Solution:

An **isobaric** process is one in which the **pressure** remains **constant**.

Hence, the correct answer is :

(A) pressure is constant.

Question174

The average translational kinetic energy of nitrogen (molar mass 28) molecules at a particular temperature is 0.042 eV . The translational kinetic energy of oxygen molecules (molar mass 32) in eV at double the temperature is

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Options:

A. 0.021

B. 0.048

C. 0.056

D. 0.084

Answer: D

Solution:

$E_{(N_2)} = 0.042eV$

Translational Kinetic Energy is given by,

$$E = \frac{3}{2}kT$$

$$\therefore \quad E \propto T$$

$$\therefore \quad \frac{E_{(N_2)}}{E_{(O_2)}} = \frac{T_1}{T_2}$$

$$\therefore \quad \frac{0.042}{E_{(O_2)}} = \frac{T}{2\,T}$$

$$\therefore \quad E_{(O_2)} = 0.084eV$$

Question175

The first operation involved in a carnot cycle is

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Options:

A. isothermal expansion.

B. adiabatic expansion.

C. isothermal compression.

D. adiabatic compression.

Answer: A

Solution:

In a Carnot cycle, the first process is the reversible isothermal expansion. Here's a brief explanation of the Carnot cycle sequence:

Isothermal Expansion: The working substance expands at a constant high temperature, absorbing heat from the hot reservoir.

Adiabatic Expansion: The gas continues to expand without exchanging heat, causing its temperature to drop.

Isothermal Compression: The gas is compressed at a constant low temperature, releasing heat to the cold reservoir.

Adiabatic Compression: The gas is compressed without heat transfer, which raises its temperature back to the initial high temperature.

Since the first step involves isothermal expansion, the correct option is:

Option A: isothermal expansion.

Question176

The temperature at which r.m.s. velocity of hydrogen molecules is 4.5 times that of an oxygen molecule at $47^{\circ}\mathrm{C}$ is (Molecular weight of hydrogen and oxygen molecules are 2 and 32 respectively)

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Options:

A. $47^{\circ}\mathrm{C}$

B. $132^{\circ}\mathrm{C}$

C. $320^{\circ}\mathrm{C}$

D. $405^{\circ}\mathrm{C}$

Answer: B

Solution:

We are tasked with finding the temperature at which the root mean square (r.m.s.) velocity of hydrogen molecules is 4.5 times that of oxygen molecules at $47^{\circ}\mathrm{C}$. For this, we use the formula for r.m.s. velocity:

$$\mathrm{V}_{\mathrm{rms}}=\sqrt{\frac{3\mathrm{RT}}{\mathrm{M}}}$$

Given that the r.m.s. velocity of hydrogen ($\mathrm{V}_{\mathrm{H}_{\mathrm{rms}}}$) is 4.5 times the r.m.s. velocity of oxygen ($\mathrm{V}_{\mathrm{O}_{\mathrm{rms}}}$), we can express this relationship as:

$$\mathrm{V}_{\mathrm{H}_{\mathrm{rms}}}=4.5\times\mathrm{V}_{\mathrm{O}_{\mathrm{rms}}}$$

Replacing the velocities with their respective r.m.s. formulas, we have:

$$\sqrt{\frac{3\mathrm{RT}}{M_{\mathrm{H}}}}=4.5\times\sqrt{\frac{3\mathrm{R}\cdot 320}{32}}$$

Simplifying the expression for oxygen at $47^{\circ}\mathrm{C}$, which is $320\,\mathrm{K}$, we get:

$$\sqrt{\frac{3\mathrm{RT}}{M_{\mathrm{H}}}}=4.5\times\sqrt{30\mathrm{R}}$$

Squaring both sides yields:

$\frac{3RT}{M_H} = 20.25 \times 30R$

Given that the molecular weight of hydrogen (M_H) is 2, we substitute to find T:

$3RT = 20.25 \times 30R \times 2$

Solving for T, we have:

$T = 20.25 \times 2 = 405\,K$

Converting from Kelvin to Celsius gives:

$T = 132^\circ C$

Question177

A sample of oxygen gas and a sample of hydrogen gas both have the same mass, same volume and the same pressure. The ratio of their absolute temperature is (Molecular wt. of $O_2 \& H_2$ is 32 and 2 respectively)

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Options:

A. 1 : 4

B. 1 : 8

C. 16 : 1

D. 12 : 1

Answer: C

Solution:

The ideal gas law is given by:

$PV = nRT$

Where:

P is the pressure,

V is the volume,

n is the number of moles,

R is the ideal gas constant,

T is the absolute temperature.

For the two gases, since the mass, volume, and pressure are the same for both oxygen (O_2) and hydrogen (H_2), we can set up the following expressions for each gas:

For oxygen:

$$PV = n_{O_2} R T_{O_2}$$

For hydrogen:

$$PV = n_{H_2} R T_{H_2}$$

Since PV is the same for both gases, we have:

$$n_{O_2} R T_{O_2} = n_{H_2} R T_{H_2}$$

This simplifies to:

$$n_{O_2} T_{O_2} = n_{H_2} T_{H_2}$$

The number of moles (n) is given by:

$$n = \frac{\text{mass}}{\text{molar mass}}$$

Let m be the mass of each gas. Then:

For oxygen:

$$n_{O_2} = \frac{m}{32}$$

For hydrogen:

$$n_{H_2} = \frac{m}{2}$$

Substitute into the equation:

$$\frac{m}{32} T_{O_2} = \frac{m}{2} T_{H_2}$$

Cancel m from both sides:

$$\frac{1}{32} T_{O_2} = \frac{1}{2} T_{H_2}$$

Cross-multiply to find the ratio of temperatures:

$$2 T_{O_2} = 32 T_{H_2}$$

Simplify:

$$T_{O_2} = 16 T_{H_2}$$

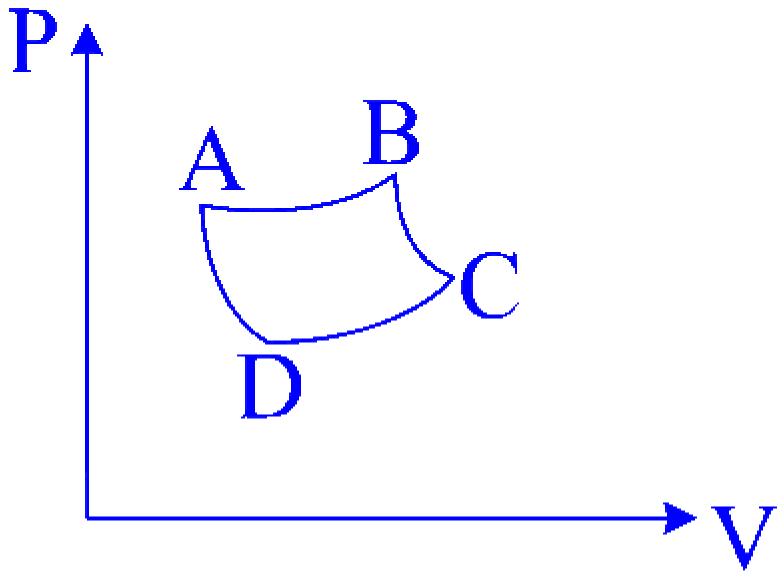
Thus, the ratio of the absolute temperatures is:

$$T_{O_2} : T_{H_2} = 16 : 1$$

The correct option is **Option C:** $16 : 1$.

Question178

The P-V graph of an ideal gas, cycle is shown. The adiabatic process is described by the region



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Options:

A. AB and BC

B. AB and CD

C. AD and BC

D. BC and CD

Answer: C

Solution:

The adiabatic curve is steeper (has a greater slope).This steepness reflects the rapid change in pressure with volume during an adiabatic process, due to the absence of heat transfer which allows the gas to expand or contract more quickly in response to changes in volume. In the given $\mathrm{P}-\mathrm{V}$ graph, adiabatic process is shown by region AD and BC only as their slope is greater.

Question179

Railway track is made of steel segments separated by small gaps to allow for linear expansion. The segment of track is 10 m long when laid at temperature $17^{\circ}\mathrm{C}$. The maximum temperature that can be reached is $45^{\circ}\mathrm{C}$. Increase in length of the segment of railway track is ' x ' $\times 10^{-5}$ m. The value of ' x ' is $\left(\alpha_{\text{steel}} = 1.2 \times 10^{-5} /{ }^{\circ}\mathrm{C}\right)$

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Options:

A. 168

B. 204

C. 336

D. 530

Answer: C

Solution:

The increase in length of a segment of railway track due to thermal expansion can be calculated using the formula for linear expansion:

$\Delta L = L_0 \cdot \alpha \cdot \Delta T$

where:

ΔL is the change in length of the track,

$L_0 = 10\,\mathrm{m}$ is the original length of the segment,

$\alpha = 1.2 \times 10^{-5}\,/{}^{\circ}\mathrm{C}$ is the coefficient of linear expansion for steel,

$\Delta T = 45^{\circ}\mathrm{C} - 17^{\circ}\mathrm{C} = 28^{\circ}\mathrm{C}$ is the change in temperature.

Plugging the values into the formula gives:

$\Delta L = 10\,\mathrm{m} \times 1.2 \times 10^{-5}\,/{}^{\circ}\mathrm{C} \times 28^{\circ}\mathrm{C}$

Calculating further:

$\Delta L = 10 \times 1.2 \times 10^{-5} \times 28 = 3.36 \times 10^{-3}\,\mathrm{m}$

The increase in length in terms of $x \times 10^{-5}$ m is:

$\Delta L = 336 \times 10^{-5}$ m

Thus, the value of x is 336.

The correct option is **Option C: 336**.

Question180

At S.T.P., the mean free path of gas molecule is 1500 d , where ' d ' is diameter of molecule. What will be the mean free path at 373 K at constant volume?

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Options:

A. 1500 d

B. $\frac{373}{273} \times 1500$ d

C. $\frac{273}{373} \times 1500$ d

D. $\sqrt{\frac{373}{273}} \times 1500$ d

Answer: B

Solution:

The mean free path of gas molecules at standard temperature and pressure (S.T.P.) is given by:

$\lambda_0 = 1500d$

where λ_0 is the mean free path at S.T.P., and d is the diameter of a gas molecule.

At constant volume, the mean free path λ is affected by temperature according to the relationship:

$\lambda \propto \frac{T}{P}$

Since the pressure remains constant (as volume is constant), the relationship simplifies to:

$\lambda \propto T$

Thus, to find the mean free path at a new temperature $T_1 = 373\,\text{K}$, we use the ratio of the temperatures:

$\lambda_1 = \left(\frac{T_1}{T_0}\right)\lambda_0$

Substituting the known temperatures:

$T_0 = 273\,\mathrm{K}$ (S.T.P.)

$T_1 = 373\,\mathrm{K}$

The mean free path at 373 K becomes:

$\lambda_1 = \left(\frac{373}{273}\right) \times 1500d$

Thus, the correct answer is Option B:

$\frac{373}{273} \times 1500$ d

Question181

One mole of an ideal gas at an initial temperature of ' T ' K does ' $6R$ ' 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 $\left(\mathrm{R} = 8.31\ \mathrm{J\ mole}^{-1}\ \mathrm{K}^{-1}\right)$

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Options:

A. $(\mathrm{T} + 4 \cdot 2)\mathrm{K}$

B. $(\mathrm{T} - 4 \cdot 2)\mathrm{K}$

C. $(\mathrm{T} + 4)\mathrm{K}$

D. $(\mathrm{T} - 4)\mathrm{K}$

Answer: D

Solution:

For an adiabatic process,

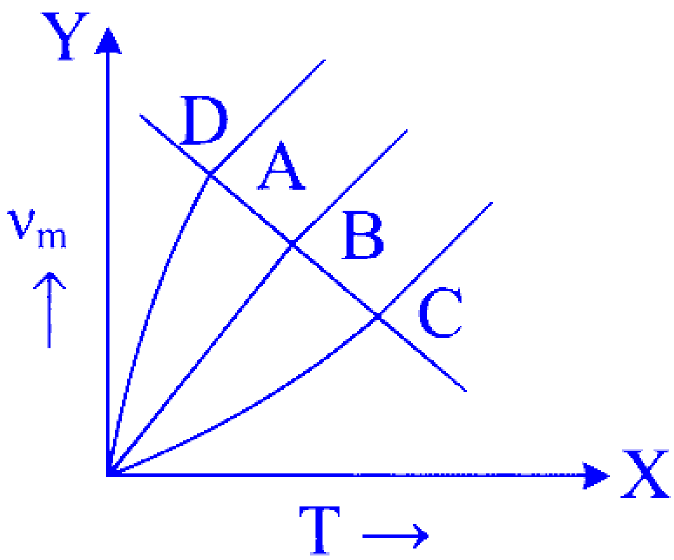
$\mathrm{W} = \frac{\mathrm{nR}(\mathrm{T_i} - \mathrm{T_f})}{\gamma - 1}$

$\therefore \quad 6R = \frac{R(T-T_f)}{\left(\frac{5}{3}-1\right)}$ ... (Given : n = 1)

$\therefore \quad T_f = (T-4)K$

Question182

The frequency ' v_m ' corresponding to which the energy emitted by a black body is maximum may vary with the temperature ' T ' of the body as shown by the curves ' A ', ' B ', ' C ' and ' D ' in the figure. Which one of these represents the correct variation?



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Options:

A. straight line D

B. curve C

C. straight line B

D. curve A

Answer: C

Solution:

1. Correct variation of frequency with temperature

Answer: **(c) straight line B**

According to Wien's displacement law, the frequency (ν_m) corresponding to the maximum energy emitted by a black body is directly proportional to its absolute temperature (T). This relationship can be expressed mathematically as $\nu_m \propto T$, or $\nu_m = kT$, where k is a constant.

A direct proportionality between two variables results in a graph that is a straight line passing through the origin. In the provided figure, curve B represents a straight line originating from the origin, indicating a linear relationship between ν_m and T.

Question183

A metal rod cools at the rate of $4^{\circ}\mathrm{C}/\mathrm{min}$ whon its temperature is $90^{\circ}\mathrm{C}$ and the rate of $1^{\circ}\mathrm{C}/\mathrm{min}$ when its temperature is $30^{\circ}\mathrm{C}$. The temperature of the surrounding is

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Options:

A. 20°C

B. 15°C

C. 10°C

D. 5°C

Answer: C

Solution:

According to Newton's law of cooling,

$$\frac{\mathrm{R}_1}{\mathrm{R}_2}=\frac{\theta_1-\theta_0}{\theta_2-\theta_0}$$

$$\therefore \quad \frac{4}{1}=\frac{90-\theta_0}{30-\theta_0}$$

$\therefore \quad 120-90=4\theta_0-\theta_0$
$\therefore \quad 3\theta_0=30$

$\therefore$ Temperature of the surroundings is,

$\theta_0=10^{\circ}\mathrm{C}$

Question184

The molecular mass of a gas having r.m.s. speed four times as that of another gas having molecular mass 32 is

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Options:

A. 2

B. 4

C. 16

D. 32

Answer: A

Solution:

$$v_{rms} \propto \frac{1}{\sqrt{M}}$$

$$\therefore \quad \frac{(v_{rms})_2}{(v_{rms})_1}=\sqrt{\frac{M_1}{M_2}}$$

Given that $(v_{rms})_2=4(v_{rms})_1$

$$\therefore \quad \sqrt{\frac{32}{M_2}}=4$$

$$\therefore \quad \frac{32}{M_2}=16$$

$$\therefore \quad M_2=2$$

Question185

At constant temperature, increasing the pressure of a gas by 5% its volume will decrease by

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Options:

A. 5%

B. 5.26%

C. 4.20%

D. 4.70%

Answer: D

Solution:

According to ideal gas law at constant temperature, $P \propto \frac{1}{V}$

$$\therefore \quad P_1 V_1 = P_2 V_2$$
$$P_1 = P$$
$$P_2 = P + \frac{5}{100} P = 1.05P$$

Substituting the values

$$PV_1 = 1.05PV_2$$
$$\therefore \quad \frac{V_2}{V_1} = \frac{1}{1.05}$$
$$\therefore \quad \frac{V_2 - V_1}{V_1} \times 100 = \frac{1 - 1.05}{1.05} \times 100$$
$$\therefore \quad \frac{\Delta V}{V_1} = -4.76\% \approx -4.7\%$$

The negative sign indicates that the volume is decreasing.

Question186

The temperature of a gas is measure of

Options:

A. the average kinetic energy of gas molecules.

B. the average potential energy of gas molecules.

C. the average distance between the molecules of a gas

D. the size of the molecules of a gas

Answer: A

Solution:

The temperature of a gas is indeed a measure of the average kinetic energy of its molecules. This is a principle that comes from kinetic molecular theory, which helps us understand the behavior of gases. According to this theory, temperature is directly proportional to the average kinetic energy of the gas molecules. This means that as the temperature increases, the average kinetic energy of the gas molecules also increases, and vice versa. The correct answer is therefore:

Option A: the average kinetic energy of gas molecules.

Here's why the other options are incorrect:

Option B: The temperature of a gas does not measure the average potential energy of gas molecules. Potential energy in the context of gas molecules often refers to the energy associated with the positions of the molecules relative to each other (e.g., due to intermolecular forces), which is not what temperature measures.

Option C: The temperature of a gas is not a measure of the average distance between the molecules of a gas. While temperature can affect the volume of gas (and thus indirectly influence average distances between molecules in some contexts), the temperature itself is specifically a measure of kinetic energy, not spatial distribution or distances between molecules.

Option D: The temperature of a gas does not measure the size of the molecules of a gas. Molecular size is related to the type of gas and its molecular structure, not to the temperature of the gas.

Question187

An ideal refrigerator has freezer at a temperature of $-13^{\circ}\mathrm{C}$. The coefficient of performance of the engine is 5. The temperature of the air (to which heat is rejected) is

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Options:

A. $320^{\circ} \mathrm{C}$

B. $39^{\circ} \mathrm{C}$

C. $325 \mathrm{~K}$

D. $325^{\circ} \mathrm{C}$

Answer: B

Solution:

Coefficient of performance, $\beta=\frac{T_2}{T_1-T_2}$

Given that, $\beta=5$ and $\mathrm{T}_2=-13^{\circ} \mathrm{C}=260 \mathrm{~K}$

$\therefore \quad \frac{260}{\mathrm{~T}_1-260}=5$
$\therefore \quad 5 \mathrm{~T}_1-1300=260$
$\therefore \quad \mathrm{T}_1=\frac{1560}{5}=312 \mathrm{~K}$
$\therefore \quad \mathrm{T}_1=39^{\circ} \mathrm{C}$

Question188

The pressure and density of a diatomic gas $\left(\gamma=\frac{7}{5}\right)$ changes adiabatically from (P, ρ) to $\left(\mathrm{P}^{\prime}, \rho^{\prime}\right)$. If $\frac{\rho^{\prime}}{\rho}=32$ then $\frac{\mathrm{P}^{\prime}}{\mathrm{P}}$ should be

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Options:

A. $\frac{1}{128}$

B. 128

C. 32

D. 64

Answer: B

Solution:

For adiabatic process, PV^{γ} = a constant

$\therefore \quad \frac{P'}{P} = \left(\frac{V'}{V}\right)^{\gamma} = \left(\frac{\rho'}{\rho}\right)^{\gamma}$

Given that, $\frac{\rho'}{\rho} = 32$ and $\gamma = \frac{7}{5}$

$\therefore \quad \frac{P'}{P} = (32)^{\frac{7}{5}} = 128$

Question189

A sphere and a cube, both of copper have equal volumes and are black. They are allowed to cool at same temperature and in same atmosphere. The ratio of their rate of loss of heat will be

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Options:

A. 1 : 1

B. $\left(\frac{\pi}{6}\right)^{\frac{2}{3}}$

C. $\left(\frac{\pi}{6}\right)^{\frac{1}{3}}$

D. $\frac{4\pi}{3}$: 1

Answer: C

Solution:

Volumes of the cube and the sphere are equal

$$\therefore \quad a^3 = \frac{4}{3}\pi r^3$$
$$\therefore \quad a = \left(\frac{4}{3}\pi r^3\right)^{\frac{1}{3}}$$

Rate of loss of radiation is proportional to the surface area of the object.

$$\therefore \quad \frac{Q_{\text{sphere}}}{Q_{\text{cube}}} = \frac{4\pi r^2}{6\mathrm{a}^2}$$
$$\therefore \quad \frac{Q_{\text{sphere}}}{Q_{\text{cube}}} = \frac{4\pi \mathrm{r}^2}{6\left(\frac{4}{3}\pi \mathrm{r}^3\right)^{\frac{2}{3}}}$$
$$\therefore \quad \frac{Q_{\text{sphere}}}{Q_{\text{cube}}} = \left(\frac{\pi}{6}\right)^{\left(\frac{1}{3}\right)}$$

Question190

A body is said to be opaque to the radiation if (a, r and t are coefficient of absorption, reflection and transmission respectively)

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Options:

A. $\mathrm{t} = 0$ and $\mathrm{a} + \mathrm{r} = 1$

B. $\mathrm{a} = \mathrm{r} = \mathrm{t}$

C. $t \neq 0$

D. $\mathrm{a} = 0, \mathrm{r} = 1, \mathrm{t} = 1$

Answer: A

Solution:

Opaque body does not transmit any radiation directly,

$$\therefore \quad t = 0$$
$$\therefore \quad a + r = 1$$

Question191

In a thermodynamic system, ΔU represents the increases in its internal energy and dW is the work done by the system then correct statement out of the following is

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Options:

A. $\Delta \mathrm{U}=\mathrm{dW}$ is an isothermal process

B. $\Delta \mathrm{U}=-\mathrm{dW}$ is an adiabatic process

C. $\Delta \mathrm{U}=-\mathrm{dW}$ is an isothermal process

D. $\Delta \mathrm{U}=\mathrm{dW}$ is an adiabatic process

Answer: B

Solution:

For an isothermal process, $\Delta \mathrm{U}=0$. According to first law of thermodynamics,

$\Delta \mathrm{Q}=\Delta \mathrm{U}+\mathrm{dW}$

For an adiabatic process,

$$\begin{aligned} & \Delta Q=0 \\ \therefore \quad & \Delta U=-dW \end{aligned}$$

$\therefore$ It is an adiabatic process.

Question192

The temperature of a gas is $-68^{\circ} \mathrm{C}$. To what temperature should it be heated, so that the r.m.s. velocity of the molecules be doubled?

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Options:

A. $357^{\circ}C$

B. $457^{\circ}C$

C. $547^{\circ}C$

D. $820^{\circ}C$

Answer: C

Solution:

$T_1 = -68^{\circ}C = -68 + 273\ K = 205\ K$

R.M.S. velocity, $v_{rms} \propto \sqrt{T}$

$$\frac{(v_{ms})_2}{(v_{ms})_1} = \sqrt{\frac{T_2}{T_1}} = 2$$

$\therefore \quad \frac{T_2}{T_1} = 4$

$\therefore \quad T_2 = 4 \times 205 = 820\ K$

$\therefore \quad T_2 = 547^{\circ}C$

Question193

A sphere, a cube and a thin circular plate all made of same material and having the same mass are heated to same temperature of $200^{\circ}C$. When these are left in a room.

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Options:

A. the sphere reaches room temperature fast

B. the cube reaches room temperature fast

C. the circular plate reaches room temperature fast

D. all will reach the room temperature simultaneously

Answer: C

Solution:

$\rho = \frac{M}{V}$;

Given: three objects are of same materials ρ is same. Also, $\mathrm{M} = $ same,

$\therefore$ volume of objects is same.

For constant volume, amongst the given objects surface area of the plate is maximum.

Hence according to Stefan's law $\frac{\mathrm{dQ}}{\mathrm{dt}} \propto \mathrm{AT}^4$

As A_{plate} is maximum, the plate will cool fastest and reaches room temperature fast.

Question194

The efficiency of a heat engine is 'η' and the coefficient of performance of a refrigerator is 'β'. Then

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Options:

A. $\eta = \frac{1}{\beta}$

B. $\eta = \frac{1}{\beta+1}$

C. $\eta\beta = \frac{1}{2}$

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

Answer: B

Solution:

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

$$\therefore \quad \eta=\frac{1}{1+\frac{T_2}{T_1-T_2}}$$

$$\therefore \quad \eta=\frac{1}{1+\beta}$$

Question195

A sample of oxygen gas and a sample of hydrogen gas both have the same mass, same volume and the same pressure. The ratio of their absolute temperature is

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Options:

A. 1 : 4

B. 4 : 1

C. 1 : 16

D. 16 : 1

Answer: D

Solution:

Given,

$p=$ Pressure
$V=$ Volume
$m=$ mass

Now, using Ideal gas law,

$pV=nRT$ .... (i)

Here $n=$ mass of gas $=m/M$

$R=$ Gas constant

$\because$ We know that p, V and m are same for hydrogen and oxygen and from Eq. (i), we have

$T=\frac{pV}{nR}=\frac{pVM}{mR}$ ..... (ii)

For oxygen, $T_{O_2} \propto M_{O_2}$

For hydrogen, $T_H \propto M_H$

Now, the ratio of T_{O_2}/T_H is

$\frac{T_{O_2}}{T_H}=\frac{M_{O_2}}{M_H}=\frac{32}{2}=\frac{16}{1}$

$\therefore$ Ratio of $T_{O_2}: T_H=16: 1$

Question196

The internal energy of a monoatomic ideal gas molecule is

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Options:

A. partly kinetic and partly potential

B. totally kinetic

C. totally potential

D. Neither kinetic nor potential

Answer: B

Solution:

The internal energy of the system is sum of kinetic and potential energy of the particles.

For an ideal gas, we assume that the particles do not intract with each other. Hence, there is no potential energy associated with the particles and the internal energy of the system will only be due to the kinetic energy of the system.

Note For a real gas, the internal energy of the system is the sum of kinetic and potential energy as the gas molecules are interacting with each other.

Question197

A gas at pressure p_0 is contained in a vessel. If the masses of all the molecules are halved and their velocities are doubled, then the resulting pressure would be equal to

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Options:

A. $4 p_0$

B. $2 p_0$

C. p_0

D. $p_0 / 2$

Answer: B

Solution:

Pressure p of the gas is given by,

$p=\frac{1}{3} \frac{m N}{V} v_{\mathrm{rms}}^2$

Where, m is mass, N is the number of moles, V is the volume and v_{rms} is the root mean square velocity of the particles of the gas.

$\therefore \quad p_1=p_0=\frac{1}{3} \frac{m_1 N}{V_1}\left(v_{\mathrm{rms}}^2\right)_1$ ..... (i)

If $m_2=\frac{m_1}{2}$ and $\left(v_{\mathrm{rms}}\right)_2=2\left(v_{\mathrm{rms}}\right)_1$

For simplicity write $v_2=2 v_1$

Hence, $p_2=\frac{1}{3} \frac{m_2 N}{V} v_2^2$ ..... (ii)

Divide Eq. (i) by Eq. (ii)

$$\frac{p_0}{p_2}=\frac{\frac{1}{3} \frac{m_1 N}{V} v_1^2}{\frac{1}{3} \frac{m_2 N}{V} v_2^2}$$

$$\Rightarrow \quad \frac{p_0}{p_2}=\frac{m_1 v_1^2}{\frac{m_1}{2}\left(2 v_1\right)^2} \Rightarrow \frac{p_0}{p_2}=\frac{1}{2}$$

$$\Rightarrow \quad p_2=2 p_0$$

$\therefore$ Resulting pressure is $2 p_0$

Question198

For an adiabatic process, which one of the following is wrong statement?

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Options:

A. Equation of state is $pV=$ constant

B. There is exchange of heat with surrounding

C. All the work is utilised to change the internal energy of the system

D. Temperature of the system changes i.e.$\Delta T \neq 0$

Answer: B

Solution:

For an adiabatic process, there is no transfer of heat.

Since, $\Delta Q=0$

From first law of thermodynamics,

$$\begin{aligned} & \Delta Q=\Delta U+\Delta W \\ \text{or} \quad & \Delta W=-\Delta U \end{aligned}$$

Hence, all work done is utilised to change in internal energy.

Question199

Which one of the following is based on convection?

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Options:

A. Heating of a copper utensil

B. Heating a room by heater

C. Heating of iron rod

D. Heat transferred from sun to earth

Answer: B

Solution:

Convection is a method of heat transfer, in which the molecules/particle travel from one place to another to transmit heat energy. Heating of copper and iron rod is an example of conduction and heat transfer from sun is due to radiation.

Question200

A carnot engine operates with source at $227^\circ\mathrm{C}$ and sink at $27^\circ\mathrm{C}$. If the source supplies $50\ \mathrm{kJ}$ of heat energy, the work done by the engine is

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Options:

A. 2 kJ

B. 5 kJ

C. 10 kJ

D. 20 kJ

Answer: D

Solution:

Given, $T_{\text{source}} \quad = 227^\circ\mathrm{C}$

$$= 227 + 273 = 500 \text{ K}$$
$$T_{\text{sink}} = 27^{\circ}\text{C} = 27 + 273 = 300 \text{ K}$$

Efficiency of carnot engine, $\eta = 1 - \frac{T_{\text{sink}}}{T_{\text{source}}}$

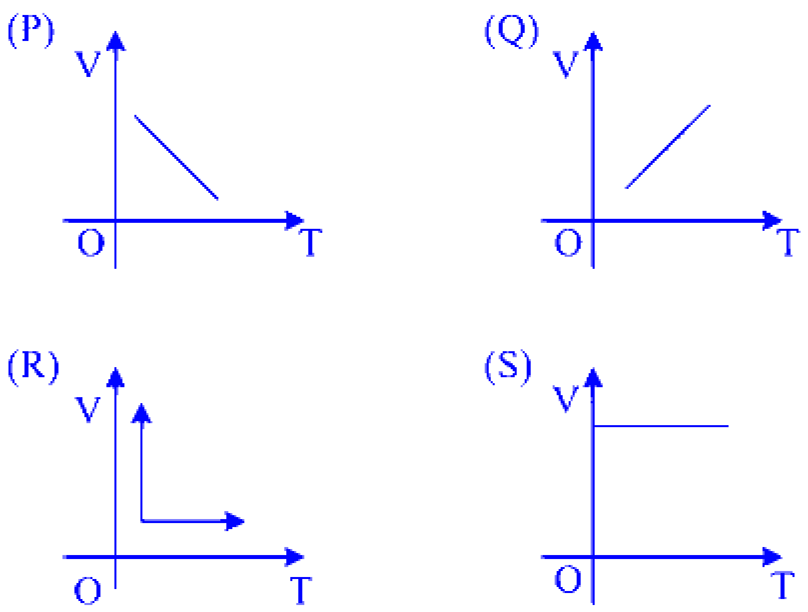
$= 1 - \frac{300}{500} = \frac{2}{5}$

Also, efficiency, $\eta = \frac{\text{Work done by engine}}{\text{Heat supplied}}$

$$\frac{2}{5} = \frac{W}{50}$$
$$\Rightarrow \quad W = 20 \text{ kJ}$$

Question201

Which one of the following represents correctly the variation of volume (V) of an ideal gas with temperature (T) under constant pressure conditions?



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Options:

A. P

B. Q

C. R

D. S

Answer: B

Solution:

According to Charles's Law, the volume of an ideal gas is directly proportional to its absolute temperature when pressure is held constant. i.e., $V \propto T$

This is depicted by graph Q.

Question202

dQ is the heat energy supplied to an ideal gas under isochoric conditions. If dU and dW denote the change in internal energy and the work done respectively then

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Options:

A. $dQ = dW$

B. $dQ > dU$

C. $dQ < dU$

D. $dQ = dU$

Answer: D

Solution:

Under isochoric (constant volume) conditions, the heat energy (dQ) supplied to an ideal gas contributes solely to the change in its internal energy (dU).

Mathematically, this can be expressed as dQ = dU + dW

$\Rightarrow dQ = dU \quad (\because dW = 0)$

Question203

A black body at temperature $127^{\circ} \mathrm{C}$ radiates heat at the rate of $5 \mathrm{~cal} / \mathrm{cm}^2 \mathrm{~s}$. At a temperature $927^{\circ} \mathrm{C}$, its rate of emission in units of $\mathrm{cal} / \mathrm{cm}^2 \mathrm{~s}$ will be

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Options:

A. 405

B. 35

C. 45

D. 350

Answer: A

Solution:

From Stefan – Boltzmann's Law

$$E=\sigma T^4$$
$$\Rightarrow E \propto T^4$$

$$\begin{aligned} \therefore \quad \frac{\mathrm{E}_1}{\mathrm{E}_2} & =\left(\frac{\mathrm{T}_1}{\mathrm{~T}_2}\right)^4=\left(\frac{400}{1200}\right)^4 \\ \frac{\mathrm{E}_1}{\mathrm{E}_2} & =\frac{1}{81} \\ \mathrm{E}_2 & =81 \times \mathrm{E}_1 \\ & =81 \times 5 \\ & =405 \mathrm{~cal} / \mathrm{cm}^2 \mathrm{~s} \end{aligned}$$

Question204

A Carnot engine has the same efficiency between (i) $100 \mathrm{~K}$ and $600 \mathrm{~K}$ and (ii) TK and $960 \mathrm{~K}$. The temperature T in kelvin of the sink is

Options:

A. 120

B. 160

C. 240

D. 320

Answer: B

Solution:

Efficiency of a carnot engine is $\eta = 1 - \frac{T_C}{T_H}$

For case (i),

$\mathrm{T_C = 100\ K}$ and $\mathrm{T_H = 600\ K}$

$\therefore \quad \eta_1 = 1 - \frac{100}{600} = \frac{5}{6}$

For case (ii),

$\mathrm{T_C = TK}$ and $\mathrm{T_H = 960\ K}$

$\therefore \quad \eta_2 = 1 - \frac{\mathrm{T}}{960}$

Given $\eta_1 = \eta_2$

$$\therefore \quad \frac{5}{6} = 1 - \frac{\mathrm{T}}{960}$$
$$\frac{5}{6} = \frac{960 - \mathrm{T}}{960}$$

Solving for T, we get $\mathrm{T = 160\ K}$

Question205

For an ideal gas the density of the gas is ρ_0 when temperature and pressure of the gas are T_0 and P_0 respectively. When the temperature of the gas is $2\ \mathrm{T_0}$, its pressure will be $3\mathrm{P_0}$. The new density will be

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Options:

A. $\frac{3}{2} \rho_0$

B. $\frac{4}{3} \rho_0$

C. $\frac{3}{4} \rho_0$

D. $\frac{2}{3} \rho_0$

Answer: A

Solution:

Density $\propto \mathrm{P} / \mathrm{T}$

So, $\frac{\mathrm{d}_2}{\mathrm{~d}_1}=\frac{\mathrm{P}_2}{\mathrm{~T}_2} \times \frac{\mathrm{T}_1}{\mathrm{P}_1}$

$\therefore \quad$ The new density is:

$$\mathrm{d}_2=\rho_0 \times \frac{3 \mathrm{P}_0}{2 \mathrm{~T}_0} \times \frac{\mathrm{T}_0}{\mathrm{P}_0}$$

$$\mathrm{d}_2=\frac{3}{2} \rho_0$$

Question206

The temperature gradient in a rod of length $75 \mathrm{~cm}$ is $40^{\circ} \mathrm{C} / \mathrm{m}$. If the temperature of cooler end of the rod is $10^{\circ} \mathrm{C}$, then the temperature of hotter end is

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Options:

A. $50^{\circ} \mathrm{C}$

B. $40^{\circ} \mathrm{C}$

C. 35°C

D. 25°C

Answer: B

Solution:

We know

$$T_g = \frac{T_1 - T_2}{x}$$
$$\Rightarrow \frac{T_1 - 10}{0.75} = 40$$

$\therefore$ Temperature of the hotter end is:

$$T_1 = (40 \times 0.75) + 10$$
$$T_1 = 40^\circ C$$

Question207

A black body radiates maximum energy at wavelength 'λ' and its emissive power is 'E'. Now due to a change in temperature of that body, it radiates maximum energy at wavelength $\frac{\lambda}{3}$. At that temperature emissive power is

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Options:

A. 16 : 1

B. 256 : 1

C. 81 : 1

D. 128 : 1

Answer: C

Solution:

$\therefore$ Emissive power of black body is, From Wien's Law:

$$E = \sigma T^4$$
$$\lambda = \frac{b}{T}$$
$$\therefore \quad E = \frac{\sigma b^4}{\lambda^4}$$
$$\therefore \quad \frac{E_2}{E_1} = \frac{\lambda_1^4}{\lambda_2^4} = \frac{\lambda^4}{\left(\frac{\lambda}{3}\right)^4} = \frac{81}{1}$$

Question208

For polyatomic gases, the ratio of molar specific heat at constant pressure to constant volume is ($f =$ degrees of freedom)

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Options:

A. $\frac{2+f}{3+f}$

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

C. $\frac{3+f}{4+f}$

D. $\frac{4+f}{3+f}$

Answer: D

Solution:

For polyatomic gases, molar-specific heat at constant volume is $C_V = (3+f)R$ and Molar-specific heat at constant pressure is $C_P = (4+f)R$

$\therefore \quad \frac{C_P}{C_V} = \frac{4+f}{3+f}$

Question209

Select the WRONG statement from the following. For an isothermal process

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Options:

A. Energy exchanged is used to do work

B. Perfect thermal equilibrium with environment

C. Equation of state PV is not constant.

D. No change internal energy.

Answer: C

Solution:

Option C is the incorrect statement for an isothermal process. An isothermal process is one in which the temperature (T) of a system remains constant throughout the process. In thermodynamics, the equation of state for an ideal gas is given by the ideal gas law, which states:

$PV = nRT$

where P is the pressure, V is the volume, n is the number of moles of gas, R is the universal gas constant, and T is the temperature.

In an isothermal process, because the temperature T is constant, the product of P and V must also remain constant for a given amount of gas with a fixed number of moles (n). This is because R is a constant and T is held constant in the process, and thus, the product PV does not change even as pressure and volume do. Therefore,

$PV = constant$

This directly contradicts Option C, which states that the equation of state PV is not constant. Since in an isothermal process for an ideal gas, PV always remains constant if the temperature is constant, Option C is the wrong statement.

Let's verify the other options for an ideal gas undergoing an isothermal process:

Option A is correct because in an isothermal expansion or compression, the energy exchanged with the surroundings is indeed used to do work. No change in internal energy occurs (Option D), due to the fact that internal energy for an ideal gas is a function of temperature alone, and in an isothermal process, temperature does not change. The energy needed to change the volume of the gas comes from or goes into the work done by or on the gas.

Option B is a somewhat ambiguous statement. It can be interpreted as saying the system is in a state of thermal equilibrium with the environment because the temperature remains constant. However, maintaining a perfect thermal equilibrium throughout the process would mean the surroundings are also at the same temperature and capable of supplying or absorbing energy without changing temperature themselves, which is a theoretical idealization.

Nevertheless, Option C is clearly the wrong statement out of the four provided when considering the definition and properties of an isothermal process.

Question210

Compare the rate of loss of heat from a metal sphere at $627^{\circ}\mathrm{C}$ with the rate of loss of heat from the same sphere at $327^{\circ}\mathrm{C}$, if the temperature of the surrounding is $27^{\circ}\mathrm{C}$. (nearly)

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Options:

A. 6.2

B. 5.3

C. 4.8

D. 7.4

Answer: B

Solution:

The heat loss is given as $\mathrm{R}=\mathrm{e}\,\sigma\mathrm{A}\left(\mathrm{T}^4-\mathrm{T}_0^4\right)$

Let surrounding temperature be denoted as T

Heat loss from the metal sphere at a temperature T_1

$\mathrm{R}_1=\mathrm{e}\sigma\mathrm{A}\left(\mathrm{T}_1^4-\mathrm{T}_0^4\right)$

Heat loss from the metal sphere at a temperature T_2

$\mathrm{R}_2=\mathrm{e}\,\sigma\mathrm{A}\left(\mathrm{T}_2^4-\mathrm{T}^4\right)$

$$\therefore \quad \frac{R_1}{R_2}=\frac{T_1^4-T^4}{T_2^4-T^4}=\frac{900^4-300^4}{600^4-300^4}$$

$$\frac{R_1}{R_2}=5.3$$

Question211

The volume of a metal block increases by 0.225% when its temperature is increased by $30^{\circ}\mathrm{C}$. Hence coefficient of linear expansion of the material of metal block is

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Options:

A. $7.5 \times 10^{-5} /{ }^{\circ} \mathrm{C}$.

B. $6.75 \times 10^{-5} /{ }^{\circ} \mathrm{C}$.

C. $2.5 \times 10^{-5} /{ }^{\circ} \mathrm{C}$.

D. $1.5 \times 10^{-5} /{ }^{\circ} \mathrm{C}$.

Answer: C

Solution:

The increase in volume is $\frac{\Delta \mathrm{V}}{\mathrm{V}} \times 100=0.225$

Change in temperature is $\Delta \mathrm{T}=30^{\circ} \mathrm{C}$

We know, $\gamma=3 \alpha$

$\therefore$ The change in volume is $\Delta \mathrm{V}=\mathrm{V} \gamma \Delta \mathrm{T}$

$$
\begin{aligned}
& \therefore \quad \frac{\Delta V}{V} \times 100=3 \alpha \Delta \mathrm{T} \times 100 \\
& \therefore \quad 0.225=3 \alpha \times 30 \times 100 \\
& \therefore \quad \alpha=\frac{0.225}{3 \times 30 \times 100} \\
& \therefore \quad \alpha=2.5 \times 10^{-5} /{ }^{\circ} \mathrm{C}
\end{aligned}
$$

Question212

A monoatomic ideal gas initially at temperature 'T_1' is enclosed in a cylinder fitted with massless, frictionless piston. By releasing the piston suddenly the gas is allowed to expand to adiabatically to a temperature 'T_2'. If 'L_1' and 'L_2' are the lengths of the gas columns before and after expansion respectively, then $\frac{T_2}{T_1}$ is

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Options:

A. $\frac{L_1}{L_2}$

B. $\frac{L_2}{L_1}$

C. $\left(\frac{L_1}{L_2}\right)^{2/3}$

D. $\left(\frac{L_2}{L_1}\right)^{2/3}$

Answer: C

Solution:

For an adiabatic process

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

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

For a monoatomic gas, $r = \frac{5}{3}$

$$\Rightarrow \gamma - 1 = \frac{5}{3} - 1 = \frac{2}{3}$$

$$V_1 = AL_1 \text{ and } V_2 = AL_2$$

$$\therefore \quad \frac{T_2}{T_1} = \left[\frac{AL_1}{AL_2}\right]^{2/3} = \left[\frac{L_1}{L_2}\right]^{2/3}$$

$$\gamma - 1 = \frac{2}{3}$$

For an adiabatic process,

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \left(\frac{V_1}{V_2}\right)^{\frac{2}{3}}$$

$V \propto L$

$$\frac{T_2}{T_1} = \left(\frac{L_1}{L_2}\right)^{\frac{2}{3}}$$

Question213

Let γ_1 be the ratio of molar specific heat at constant pressure and molar specific heat at constant volume of a monoatomic gas and γ_2 be the similar ratio of diatomic gas. Considering the diatomic gas molecule as a rigid rotator, the ratio $\frac{\gamma_2}{\gamma_1}$ is

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Options:

A. $\frac{37}{21}$

B. $\frac{27}{35}$

C. $\frac{21}{25}$

D. $\frac{35}{27}$

Answer: C

Solution:

For monoatomic gas,

$\gamma_1 = \frac{5}{3}$

For rigid diatomic gas,

$$\gamma_2 = \frac{7}{5}$$

$$\therefore \quad \frac{\gamma_2}{\gamma_1} = \frac{7}{5} \times \frac{3}{5} = \frac{21}{25}$$

Question214

The molar specific heat of an ideal gas at constant pressure and constant volume is C_p and C_v respectively. If R is universal gas constant and $\gamma = \frac{C_p}{C_v}$ then $C_v =$

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Options:

A. $\frac{1-\gamma}{1+\gamma}$

B. $\frac{1+\gamma}{1-\gamma}$

C. $\frac{\gamma-1}{R}$

D. $\frac{R}{\gamma-1}$

Answer: D

Solution:

$C_p - C_v = R$

Dividing both the sides by C_v,

$\therefore \quad \gamma - 1 = \frac{R}{C_v} \quad \ldots . \left(\because \frac{C_p}{C_v} = \gamma\right)$

$\therefore \quad C_v = \frac{R}{\gamma-1}$

Question215

A composite slab consists of two materials having coefficient of thermal conductivity K and $2K$, thickness x and $4x$ respectively. The temperature of the two outer surfaces of a composite slab are T_2 and T_1 ($T_2 > T_1$). The rate of heat transfer through the slab in a steady state is $\left[\frac{A(T_2-T_1)K}{x}\right] \cdot f$ where 'f' is equal to

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Options:

A. 1

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

C. $\frac{1}{2}$

D. $\frac{1}{3}$

Answer: D

Solution:

$$\begin{aligned} & R_{eq}=R_1+R_2 \\ \because \quad & R_1=\frac{x}{KA}, R_2=\frac{4x}{2KA} \\ \therefore \quad & R_{eq}=\frac{x}{KA}+\frac{2x}{KA}=\frac{3x}{KA} \end{aligned}$$

Rate of heat transfer of composite slab is given by,

$$\frac{dQ}{dt}=\frac{T_2-T_1}{R_{eq}}=\frac{KA(T_2-T_1)}{3x}$$

$\therefore \quad f=\frac{1}{3}$

Question216

A black sphere has radius 'R' whose rate of radiation is 'E' at temperature 'T'. If radius is made $R/3$ and temperature '$3T$', the rate of radiation will be

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Options:

A. E

B. 3E

C. 6E

D. 9E

Answer: D

Solution:

$E = eA\sigma T^4$

But for sphere, $A = 4\pi R^2$

$$\therefore \quad E = e\left(4\pi R^2\right)\sigma T^4$$
$$\therefore \quad \frac{E_1}{E_2} = \frac{R_1^2 T_1^4}{R_2^2 T_2^4}$$
$$\therefore \quad \frac{E}{E_2} = \frac{R^2 T^4}{\left(\frac{R}{3}\right)^2 (3T)^4}$$
$$\therefore \quad E_2 = 9E$$

Question217

A gas at normal temperature is suddenly compressed to one-fourth of its original volume. If $\frac{C_p}{C_v} = \gamma = 1.5$, then the increase in its temperature is

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Options:

A. 273 K

B. 373 K

C. 473 K

D. 573 K

Answer: A

Solution:

Given that, $V_2 = \frac{V_1}{4}, \frac{C_p}{C_v} = \gamma = 1.5$

As the process is sudden, it is an adiabatic expansion,

$$\therefore \quad T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$
$$\therefore \quad T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$
$$= T_1(4)^{\gamma-1}$$
$$= T_1 \times (4)^{0.5}$$
$$= 2\,T_1$$
$$T_2 - T_1 = T_1$$
$$T_2 - T_1 = 273\text{ K} \quad (\because T_1 = \text{ Normal temperature })$$

Question218

About black body radiation, which of the following is the wrong statement?

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Options:

A. For all wavelengths, intensity is same.

B. For shorter wavelengths, intensity is more.

C. For longer wavelengths, intensity is less.

D. All wavelengths are emitted by a black body.

Answer: A

Solution:

✅ Correct Answer: **A. For all wavelengths, intensity is same.** (Wrong statement)

Explanation

A **black body** emits radiation over a range of wavelengths, but the **intensity is not the same for all wavelengths**.

The intensity of radiation varies with wavelength in a characteristic way known as the **black body spectrum**.

Key points from the spectrum:

1. **Intensity is highest at a certain wavelength** (peak).
2. **For shorter wavelengths**, intensity is generally **higher** (Option B is correct).
3. **For longer wavelengths**, intensity is generally **lower** (Option C is correct).
4. A black body emits radiation at **all wavelengths** (Option D is correct), though intensity varies.

So, the statement claiming that:

“For all wavelengths, intensity is same.”

is **incorrect**, because the spectrum is not flat.

Question219

For a gas, $\frac{\mathrm{R}}{\mathrm{C_v}} = 0 \cdot 4$, where R is universal gas constant and $\mathrm{C_v}$ is molar specific heat at constant volume. The gas is made up of molecules which are

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Options:

A. rigid diatomic

B. monoatomic

C. non-rigid diatomic

D. polyatomic

Answer: A

Solution:

$$\text{Given: } \frac{R}{C_V} = 0.4$$

$$C_V = \frac{R}{0.4} = \frac{5R}{2}$$

$C_P = C_V + R$

$\therefore \quad C_P = \frac{7R}{2}$

$\gamma = \frac{C_P}{C_v} = \frac{\frac{7}{5}}{\frac{5}{2}}$

$\gamma = \frac{7}{5}$

$\therefore$ The gas is made up of rigid diatomic molecules.

Question220

Two bodies A and B at temperatures 'T_1' K and 'T_2' K respectively have the same dimensions. Their emissivities are in the ratio $1:3$. If they radiate the same amount of heat per unit area per unit time, then the ratio of their temperatures $(\mathrm{T}_1 : \mathrm{T}_2)$ is

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Options:

A. $1:3$

B. $3^{1/4}:1$

C. $9^{1/4}:1$

D. $81:1$

Answer: B

Solution:

From Stefan - Boltzmann's law

$\frac{\mathrm{dQ}}{\mathrm{dt}} = \mathrm{e}\left(\sigma \mathrm{AT}^4\right)$

Given A and $\frac{\mathrm{dQ}}{\mathrm{dt}}$ are same for both the bodies

$$\Rightarrow e_1 T_1^4 = e_2 T_2^4$$

$$\therefore \left(\frac{T_1}{T_2}\right)^4 = \frac{e_2}{e_1} = \frac{3}{1}$$

$$\Rightarrow \frac{T_1}{T_2} = \frac{\sqrt[4]{3}}{1} = \frac{3^{\frac{1}{4}}}{1}$$

Question221

If temperature of gas molecules is raised from $127^{\circ}C$ to $527^{\circ}C$, the ratio of r.m.s. speed of the molecules is respectively

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Options:

A. 1 : 2

B. 2 : 1

C. $1 : \sqrt{2}$

D. $2 : \sqrt{2}$

Answer: C

Solution:

We know

$$V_{rms} = \sqrt{\frac{3RT}{m}}$$

The temperature of the same gas molecule is raised.

$$V_{ms} \propto \sqrt{T}$$

$\therefore$ The ratio of the velocities is

$$\frac{V_1}{V_2} = \frac{\sqrt{T_1}}{\sqrt{T_2}}$$

$$\frac{V_1}{V_2} = \frac{\sqrt{400}}{\sqrt{800}}$$
$$\frac{V_1}{V_2} = \frac{1}{\sqrt{2}}$$

Convert temperatures given in centigrade to Kelvin before calculation.

Question222

According to Boyle's law, the product PV remains constant. The unit of PV is same as that of

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Options:

A. energy

B. force

C. impulse

D. momentum

Answer: A

Solution:

The units of PV can be calculated as follows:

The unit of pressure is $\mathrm{Kgm}^{-1}\ \mathrm{s}^{-2}$

The unit of volume is m^3

$\therefore$ The unit of PV is

Unit $= \mathrm{Kgm}^{-1}\ \mathrm{s}^{-2}\ \mathrm{m}^3 = \mathrm{Kgm}^2\ \mathrm{s}^{-2}$

This is a unit of energy.

Question223

The difference in length between two rods A and B is $60 \mathrm{~cm}$ at all temperatures. If $\alpha_{\mathrm{A}}=18 \times 10^{-6} /{ }^{\circ} \mathrm{C}$ and $\beta_{\mathrm{B}}=27 \times 10^{-6} /{ }^{\circ} \mathrm{C}$, the lengths of the two rods are

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Options:

A. $l_{\mathrm{A}}=200 \mathrm{~cm}, l_{\mathrm{B}}=140 \mathrm{~cm}$

B. $l_{\mathrm{A}}=180 \mathrm{~cm}, l_{\mathrm{B}}=120 \mathrm{~cm}$

C. $l_{\mathrm{A}}=160 \mathrm{~cm}, l_{\mathrm{B}}=100 \mathrm{~cm}$

D. $l_{\mathrm{A}}=120 \mathrm{~cm}, l_{\mathrm{B}}=60 \mathrm{~cm}$

Answer: B

Solution:

Given: $\Delta l=60 \mathrm{~cm}, \alpha_{\mathrm{A}}=18 \times 10^{-6} /{ }^{\circ} \mathrm{C}$,

$\alpha_B=27 \times 10^{-6} /{ }^{\circ} \mathrm{C}$

Δl is constant at all temperatures.

We know $\Delta l=l \alpha \Delta t$

Let the length of the rods at a temperature $0^{\circ} \mathrm{C}$ be l_{A} and l_{B}

$\therefore$ At temperature $\mathrm{t}^{\circ} \mathrm{C}$

$$
\begin{aligned}
& l_{\mathrm{A}} \alpha_{\mathrm{A}} \mathrm{t}_{\mathrm{A}}=l_{\mathrm{B}} \alpha_{\mathrm{B}} \mathrm{t}_{\mathrm{B}} \\
& l_{\mathrm{A}}(18) \times 10^{-6}=l_{\mathrm{B}}(27) \times 10^{-6} \quad \text{.... (i)} \\
& \Delta l=l_{\mathrm{A}}-l_{\mathrm{B}} \\
& \Delta l=\frac{3}{2} l_{\mathrm{B}}-l_{\mathrm{B}} \quad \text{.... from (i)} \\
& \Delta l=\frac{1}{2} l_{\mathrm{B}}
\end{aligned}
$$

$\therefore \quad l_{\mathrm{B}}=2 \Delta l$

$\therefore \quad l_{\mathrm{B}}=2 \times 60=120 \mathrm{~cm}$

$\therefore \quad l_{\mathrm{A}}=\frac{3}{2} \times 120=180 \mathrm{~cm}$

Question224

An ideal gas expands adiabatically. $(\gamma=1\cdot5)$ To reduce the r.m.s. velocity of the molecules 3 times, the gas has to be expanded

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Options:

A. 81 times

B. 27 times

C. 9 times

D. 3 times

Answer: A

Solution:

We know,

$$V_{\text{rms}}=\sqrt{\frac{3RT}{M_0}}$$
$$\Rightarrow T \propto V^2$$
$$\frac{T_2}{T_1}=\frac{V_2^2}{V_1^2}=\frac{\left(\frac{V_1}{3}\right)^2}{V_1^2}=\frac{1}{9} \quad \text{.... (i)}$$
Also, $TV^{\gamma-1}=$ Constant
$$\Rightarrow \frac{V_2}{V_1}=\left(\frac{T_1}{T_2}\right)^{\frac{1}{\gamma-1}}$$
$$\frac{V_2}{V_1}=(9)^2=81$$

Question225

Two spherical black bodies of radii 'r_1' and 'r_2' at temperature 'T_1' and 'T_2' respectively radiate power in the ratio $1:2$ Then $r_1:r_2$ is

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Options:

A. $\frac{1}{2}\left(\frac{T_2}{T_1}\right)^4$

B. $\frac{1}{\sqrt{2}}\left(\frac{T_2}{T_1}\right)^2$

C. $2\left(\frac{T_1}{T_2}\right)^4$

D. $2\left(\frac{T_1}{T_2}\right)^2$

Answer: B

Solution:

Power Radiated by black body, $P = \sigma A T^4$

$\therefore$ For first black body:

$P_1 = \sigma 4\pi r_1^2 T_1^4$

$\therefore$ For second black body:

$P_2 = \sigma 4\pi {r_2}^2 {T_2}^4$

$\therefore$ The ratio will be:

$$\frac{P_1}{P_2} = \frac{\sigma 4\pi r_1^2 T_1^4}{\sigma 4\pi r_2^2 T_2^4}$$
$$\frac{1}{2} = \frac{r_1^2 T_1^4}{r_2^2 T_2^4}$$
$$\frac{r_1^2}{r_2^2} = \frac{1}{2}\frac{T_2^4}{T_1^4}$$
$$\frac{r_1}{r_2} = \frac{1}{\sqrt{2}}\left(\frac{T_2}{T_1}\right)^2$$

Question226

The rate of flow of heat through a metal rod with temperature difference $40^{\circ}\mathrm{C}$ is $1600 \mathrm{~cal} / \mathrm{s}$. The thermal resistance of metal rod in $^{\circ}\mathrm{Cs} / \mathrm{cal}$ is

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Options:

A. 0.025

B. 0.25

C. 2.5

D. 40

Answer: A

Solution:

Given: rate of flow of heat (conduction rate) $P_{\text{cond}} = 1600 \mathrm{~cal} / \mathrm{s}$

Thermal resistance,

$$R_T = \frac{\Delta T}{P_{\text{cond}}}$$
$$R_T = \frac{40}{1600}$$
$$R_T = 0.025^{\circ}\mathrm{Cs} / \mathrm{cal}$$

Question227

If the temperature of a hot body is increased by 50%, then the increase in the quantity of emitted heat radiation will be approximately

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Options:

A. 125%

B. 200%

C. 300%

D. 400%

Answer: D

Solution:

Given: $T_2 = T_1 + \frac{50}{100} T_1$

$T_2 = 1.5 T_1$

According to Stefan's law,

$\frac{Q}{At} = \sigma T^4$

Percentage change in radiation is,

$$\Delta E\% = \frac{T_2^4 - T_1^4}{T_1^4} \times 100$$

$$\Delta E\% = \frac{(1.5)^4 T_1^4 - T_1^4}{T_1^4} \times 100$$

$$\Delta E\% \approx 400\%$$

Question228

A monoatomic gas at pressure 'P', having volume 'V' expands isothermally to a volume '2 V' and then adiabatically to a volume ' 16 V'. The final pressure of the gas is (Take $\gamma = 5/3$)

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Options:

A. $P/64$

B. $P/32$

C. 16P

D. 32P

Answer: A

Solution:

After isothermal expansion:

$$P_1 V_1 = P_2 V_2$$

$$P_2 = P_1 \frac{V_1}{V_2}$$

$$P_2 = P_1 \frac{V}{2V}$$

$$P_2 = \frac{P}{2}$$

After adiabatic expansion:

$$\mathrm{P}_2\ \mathrm{V}_2^\gamma = \mathrm{P}_3\ \mathrm{V}_3^\gamma$$

$$\mathrm{P}_3 = \mathrm{P}_2\left(\frac{\mathrm{V}_2}{\mathrm{V}_3}\right)^\gamma$$

$$\mathrm{P}_3 = \frac{\mathrm{P}}{2}\left(\frac{2\ \mathrm{V}}{16\ \mathrm{V}}\right)^{5/3}$$

$$\mathrm{P}_3 = \frac{\mathrm{P}}{2}\left(\frac{1}{8}\right)^{5/3}$$

$$\mathrm{P}_3 = \frac{\mathrm{P}}{64}$$

Question229

A diatomic gas $\left(\gamma = \frac{7}{5}\right)$ is compressed adiabatically to volume $\frac{V_i}{32}$ where V_i is its initial volume. The initial temperature of the gas is T_i in Kelvin and the final temperature is 'xT_i'. The value of 'x' is

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Options:

A. 5

B. 4

C. 3

D. 2

Answer: B

Solution:

For adiabatic process: $\mathrm{TV}^{\gamma-1}=$ Constant

$\therefore$ Initially:

$\mathrm{T_i V^{\frac{7}{5}-1}}=$ Constant

$\therefore$ Final condition:

$\mathrm{x T_f V^{\frac{7}{5}-1}}=$ Constant

So,

$$T_i V^{\frac{7}{5}-1}=x T_f V^{\frac{7}{5}-1}$$
$$T^{\frac{2}{5}}=x T\left(\frac{V}{32}\right)^{\frac{2}{5}}$$
$$x=4$$

Question230

If a gas is compressed isothermally then the r.m.s. velocity of the molecules

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Options:

A. decreases.

B. increases.

C. remains the same.

D. first decreases and then increases.

Answer: C

Solution:

The root-mean-square (rms) velocity of gas molecules is,

$$v_{r,m.s} = \sqrt{\frac{3kT}{m}}$$

$\Rightarrow v_{rms} \propto \sqrt{T}$ for a given gas.

As the temperature is constant in isothermal process, the r.m.s velocity remains the same.

Question231

A black body radiates maximum energy at wavelength 'λ' and its emissive power is 'E' Now due to change in temperature of that body, it radiates maximum energy at wavelength $\frac{2\lambda}{3}$. At that temperature emissive power is

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Options:

A. $\frac{81}{16}$

B. $\frac{27}{32}$

C. $\frac{18}{10}$

D. $\frac{9}{4}$

Answer: A

Solution:

From Stefan-Boltzmann's law,

$$P = \frac{dQ}{dt} = A\sigma T^4$$

Also, from Wien's displacement law,

$$\lambda_{max} = \frac{b}{T}(b \rightarrow \text{ Wien's constant })$$
$$\Rightarrow T = \frac{b}{\lambda}$$

$\therefore \quad P = A \cdot \sigma\left(\frac{b}{\lambda}\right)^4$

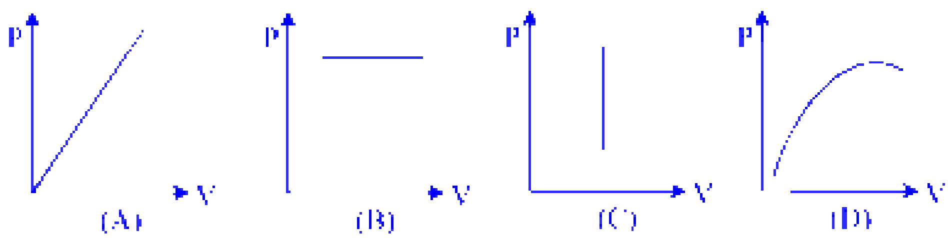
$\Rightarrow P \propto \frac{1}{(\lambda)^4}$

$\therefore$ Ratio of power dissipated is $\frac{P_2}{P_1} = \left(\frac{\lambda_1}{\lambda_2}\right)^4$ Given $\lambda_1 = \lambda$ and $\lambda_2 = \frac{2\lambda}{3}$

$\therefore \quad \frac{P_2}{P_1} = \frac{(\lambda)^4}{\left(\frac{2\lambda}{3}\right)^4} = \frac{81}{16}$

Question232

Which of the following graphs between pressure (P) and volume (V) correctly shows isochoric changes?



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Options:

A. D

B. B

C. C

D. A

Answer: C

Solution:

Isochoric processes are those in which the volume of the system remains constant. In a Pressure-Volume (P-V) graph, an isochoric process is represented by a vertical line because the volume does not change, while the pressure can vary.

Looking at the provided graph :

- Graph A shows a diagonal line, indicating changes in both pressure and volume.
- Graph B shows a horizontal line, indicating constant pressure, not constant volume. This represents an isobaric process.
- Graph C shows a vertical line, which is characteristic of an isochoric process, where the volume remains constant while the pressure changes.
- Graph D shows a curve, indicating that both pressure and volume are changing.

Therefore, the correct option that represents an isochoric process is :

Option C : C

Question233

A metal rod $2 \mathrm{~m}$ long increases in length by $1.6 \mathrm{~mm}$, when heated from $0^{\circ} \mathrm{C}$ to $60^{\circ} \mathrm{C}$. The coefficient of linear expansion of metal rod is

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Options:

A. $1.33 \times 10^{-5} /{ }^{\circ} \mathrm{C}$

B. $1.66 \times 10^{-5} /{ }^{\circ} \mathrm{C}$

C. $1.33 \times 10^{-3} /{ }^{\circ} \mathrm{C}$

D. $1.66 \times 10^{-3} /{ }^{\circ} \mathrm{C}$

Answer: A

Solution:

We know,

Coefficient of Linear expansion $\alpha=\frac{\mathrm{L}_2-\mathrm{L}_1}{\mathrm{~L}_1 \Delta \mathrm{T}}$ ...... (i)

Given: $\Delta \mathrm{T}=60-0=60^{\circ} \mathrm{C}$

$\mathrm{L}_1=2 \mathrm{~m}$ and $\mathrm{L}_2=2.0016$

Substituting the given values into (i),

$\alpha=\frac{.0016}{120}=1.33 \times 10^{-5} /{ }^{\circ} \mathrm{C}$

Question234

We have a jar filled with gas characterized by parameters $\mathrm{P}, \mathrm{V}, \mathrm{T}$ and another jar B filled with gas having parameters $2\mathrm{P}, \frac{\mathrm{V}}{4}, 2\ \mathrm{T}$, where symbols have their usual meaning. The ratio of number of molecules in jar A to those in jar B is

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Options:

A. 1 : 1

B. 1 : 2

C. 2 : 1

D. 4 : 1

Answer: D

Solution:

According to the gas equation, $\mathrm{PV}=\mathrm{Nk}_{\mathrm{B}} \mathrm{T}$

For the first gas, we have,

$\mathrm{PV}=\mathrm{N}_1 \mathrm{k}_{\mathrm{B}} \mathrm{T}$ ..... (i)

For the second gas, we have,

$$(2 \mathrm{P})\left(\frac{\mathrm{V}}{4}\right)=\mathrm{N}_2 \mathrm{k}_{\mathrm{B}}(2\ \mathrm{T})$$

$\mathrm{PV}=4\ \mathrm{N}_2 \mathrm{k}_{\mathrm{B}} \mathrm{T}$ .... (ii)

From equations (i) and (ii)

$\mathrm{N}_1=4\ \mathrm{N}_2 \Rightarrow \frac{\mathrm{N}_1}{\mathrm{N}_2}=4$

Question235

An insulated container contains a monoatomic gas of molar mass 'm '. The container is moving with velocity 'V'. If it is stopped suddenly, the change in temperature of a gas is [R is gas constant]

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Options:

A. $\frac{\mathrm{MV}^2}{\mathrm{R}}$

B. $\frac{MV^2}{2R}$

C. $\frac{\mathrm{MV}^2}{3\mathrm{R}}$

D. $\frac{3\mathrm{MV}^2}{2\mathrm{R}}$

Answer: C

Solution:

Kinetic energy loss of the gas is

$\Delta \mathrm{E}=\frac{1}{2} M V^2 \cdot \mathrm{n}$ ..... (i) ....(where n is the no. of moles of the gas)

Heat gained by the gas due to temperature change $\Delta \mathrm{T}$ is $\Delta Q={ }_n C_V \Delta T$

But, $\mathrm{C}_{\mathrm{V}}=\frac{3}{2} \mathrm{R}$ ....(gas is monoatomic)

$\therefore \quad \Delta \mathrm{Q}=\frac{3}{2} \mathrm{R} \cdot \mathrm{n} \Delta \mathrm{T}$ ..... (ii)

Equating (i) and (ii),

$$\Delta \mathrm{E}=\Delta \mathrm{Q}$$
$$\frac{1}{2} \mathrm{MV}^2 \cdot \mathrm{n}=\frac{3}{2} \mathrm{R} \cdot \mathrm{n} \Delta \mathrm{T}$$
$$\Delta \mathrm{T}=\frac{\mathrm{MV}}{3 \mathrm{R}}$$

Question236

In a vessel, the ideal gas is at a pressure P. If the mass of all the molecules is halved and their speed is doubled, then resultant

pressure of the gas will be

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Options:

A. 4P

B. 2P

C. P

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

Answer: B

Solution:

We know,

$$v_{ms}^2 = \frac{3PV}{Nm}$$
$$\Rightarrow P = \frac{1}{3}\frac{mN}{V}v_{mms}^2$$
$$\Rightarrow P \propto v_{ms}^2$$
$$\therefore \quad \frac{P_2}{P_1} = \frac{m_2}{m_1} \times \left[\frac{v_2}{v_1}\right]^2$$
$$= \frac{\left(\frac{m_1}{2}\right)}{m_1}\left[\frac{2v_1}{v_1}\right]^2$$
$$\ldots\ldots\left(\because \text{ given } m_2 = \frac{m_1}{2} \text{ and } v_2 = 2v_1\right)$$

$$\frac{P_2}{P_1} = 2$$
$$\therefore \quad P_2 = 2P_1$$
$$= 2P \quad \ldots.(\text{given } P_1 = P)$$

Question237

The average force applied on the walls of a closed container depends on T^x where T is the temperature of an ideal gas. The value of 'x' is

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Options:

A. 4

B. 3

C. 2

D. 1

Answer: D

Solution:

$$P = \frac{F}{A}$$

$\therefore \quad P \propto F \quad$ ..... (i)

From Ideal Gas Equation,

$P = \frac{nRT}{V}$

When V remains constant,

$P \propto T$ ..... (ii)

Comparing (i) and (ii)

$F \propto T^x$

$\therefore \quad x = 1$

Question238

A black body radiates maximum energy at wavelength 'λ' and its emissive power is E. Now due to change in temperature of that body, it radiates maximum energy at wavelength $\frac{2\lambda}{3}$. At that temperature emissive power is

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Options:

A. $\frac{51E}{8}$

B. $\frac{81E}{16}$

C. $\frac{61E}{27}$

D. $\frac{71E}{19}$

Answer: B

Solution:

From Wien's Displacement law,

$\lambda_{\max} = \frac{b}{T} \Rightarrow T = \frac{b}{\lambda_{\max}}$

From Stefan-Boltzmann law

$E = \sigma T^4 = \sigma\left(\frac{b}{\lambda_{\max}}\right)^4$

Let the new emissive power be E′.

$$\therefore \quad E' = \sigma\left(\frac{b}{\frac{2\lambda_{\max}}{3}}\right)^4$$

$$E' = \frac{81}{16}E$$

Question239

A Carnot engine with efficiency 50% takes heat from a source at 600 K. To increase the efficiency to 70%, keeping the temperature of the sink same, the new temperature of the source will be

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Options:

A. 360 K

B. 1000 K

C. 900 K

D. 300 K

Answer: B

Solution:

$T_H = 600\text{k}$

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

but, $\eta = \dfrac{1}{2} \quad \ldots.(\text{Given} : \eta = 50\%)$

$\Rightarrow \dfrac{1}{2} = 1 - \dfrac{T_C}{600}$

$\therefore \quad T_C = 300K$

With $\mathrm{T_C} = 300$ K, the efficiency is increased to 70%

$\therefore$ New temperature of the source will be $\mathrm{T_{H_{new}}}$

$\therefore \quad \eta = 1 - \frac{300}{\mathrm{T_{H_{new}}}}$

$\frac{300}{\mathrm{T_{H_{new}}}} = 1 - \frac{7}{10} \quad \ldots.(\because \eta = 70\%)$

$\therefore \quad \mathrm{T_{H_{new}}} = \frac{3000}{3} = 1000$ K

Question240

A piece of metal at 850 K is dropped in to 1 kg water at 300 K. If the equilibrium temperature of water is 350 K then the heat capacity of the metal, expressed in $\mathrm{JK^{-1}}$ is $(1 \text{ cal} = 4.2 \text{ J})$

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Options:

A. 420

B. 240

C. 100

D. 500

Answer: A

Solution:

1. Calculate heat capacity of the metal

Step 1: Identify given variables and principle of calorimetry

The principle of calorimetry states that the heat lost by the hot object equals the heat gained by the cold object, assuming no heat is lost to the surroundings:

$$Q_{\text{lost}} = Q_{\text{gained}}$$

The formula for heat transfer is $Q = C\Delta T$, where C is the heat capacity and ΔT is the change in temperature.
Given:

- $T_{\text{metal, initial}} = 850$ K
- $m_{\text{water}} = 1$ kg
- $T_{\text{water, initial}} = 300$ K
- $T_{\text{equilibrium}} = 350$ K
- Specific heat capacity of water, $c_{\text{water}} = 1$ cal $\text{g}^{-1}\text{K}^{-1} = 4200$ J $\text{kg}^{-1}\text{K}^{-1}$ (using 1 cal $= 4.2$ J and 1 kg $= 1000$ g).

Step 2: Calculate the heat gained by the water

The temperature change for the water is
$\Delta T_{\text{water}} = T_{\text{equilibrium}} - T_{\text{water, initial}} = 350\text{ K} - 300\text{ K} = 50$ K.
The heat gained by the water is:

$$Q_{\text{water}} = m_{\text{water}} \cdot c_{\text{water}} \cdot \Delta T_{\text{water}}$$

$$Q_{\text{water}} = 1\text{ kg} \cdot 4200\text{ Jkg}^{-1}\text{K}^{-1} \cdot 50\text{ K}$$

$$Q_{\text{water}} = 210000\text{ J}$$

Step 3: Calculate the temperature change of the metal

The temperature change for the metal is
$\Delta T_{\text{metal}} = T_{\text{metal, initial}} - T_{\text{equilibrium}} = 850\text{ K} - 350\text{ K} = 500$ K.

Step 4: Calculate the heat capacity of the metal

The heat lost by the metal is equal to the heat gained by the water:

$$Q_{\text{metal}} = Q_{\text{water}} = 210000\text{ J}$$

The heat capacity of the metal, C_{metal}, can be found using the formula
$Q_{\text{metal}} = C_{\text{metal}} \cdot \Delta T_{\text{metal}}$:

$$C_{\text{metal}} = \frac{Q_{\text{metal}}}{\Delta T_{\text{metal}}}$$

$$C_{\text{metal}} = \frac{210000\ \text{J}}{500\ \text{K}}$$

$$C_{\text{metal}} = 420\ \text{JK}^{-1}$$

Answer:

(A) **420**

Question241

Heat energy is incident on the surface at the rate of X J/min . If 'a' and 'r' represent coefficient of absorption and reflection respectively then the heat energy transmitted by the surface in 't' minutes is

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Options:

A. $(a+r)xt$

B. $\frac{(a+r)}{xt}$

C. $-(a+r)xt$

D. $\frac{xt}{(a+r)}$

Answer: A

Solution:

$\text{We know} \quad 1 = a + r + t_r$

$\Rightarrow t_r = 1 - (a + r)$

$\text{Heat transmitted} = t_r \times \text{ time}$

$\therefore \quad Q = X \times (1 - a + r) \times t \ldots (\text{Substituting for } t_r)$

$Q = X(1 - a + r) \times t$

Question242

A sample of gas at temperature T is adiabatically expanded to double its volume. The work done by the gas in the process is $\left(\frac{C_P}{C_V}=\gamma=\frac{3}{2}\right)$ (R = gas constant)

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Options:

A. $\mathrm{TR}(\sqrt{2}-2)$

B. $\frac{\mathrm{T}}{\mathrm{R}}(\sqrt{2}-2)$

C. $\frac{\mathrm{R}}{\mathrm{T}}(2-\sqrt{2})$

D. $\mathrm{RT}(2-\sqrt{2})$

Answer: D

Solution:

Using the formula for adiabatic expansion,

$$\mathrm{T}_1 \mathrm{~V}_1^{\gamma-1}=\mathrm{T}_2 \mathrm{~V}_2^{\gamma-1}$$
$$\mathrm{T}_1 \mathrm{~V}_1{}^{(1/2)}=\mathrm{T}_2\left(2 \mathrm{~V}_1{}^{1/2}\right) \quad \ldots\ldots(\text{Given} : \gamma=\frac{3}{2})$$
$$\therefore \quad \mathrm{T}_1=\mathrm{T}_2(\sqrt{2})$$
$$\therefore \quad \mathrm{T}_2=\frac{\mathrm{T}}{\sqrt{2}}$$

Work done

$$\mathrm{W}_{\text{adi}}=\frac{\mathrm{R}\left(\mathrm{T}-\mathrm{T}_2\right)}{\gamma-1}=\frac{\mathrm{R}\left(\mathrm{T}-\frac{\mathrm{T}}{\sqrt{2}}\right)}{\frac{1}{2}}$$
$$=\frac{\mathrm{R}(\sqrt{2}\,\mathrm{T}-\mathrm{T})}{\sqrt{2}} \times 2=\mathrm{RT}(\sqrt{2}-1)\sqrt{2}$$
$$\therefore \quad \mathrm{W}_{\text{adi}}=\mathrm{RT}(2-\sqrt{2})$$

Question243

An ideal gas in a container of volume 500 c.c. is at a pressure of $2 \times 10^{+5}\ \mathrm{N/m^2}$. The average kinetic energy of each molecule is 6×10^{-21} J. The number of gas molecules in the container is

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Options:

A. 5×10^{25}

B. 5×10^{23}

C. 25×10^{23}

D. 2.5×10^{22}

Answer: D

Solution:

$\mathrm{PV} = \mathrm{Nk_BT}$

and, K.E./molecule $= \frac{3}{2}\mathrm{k_BT} = \frac{3}{2}\frac{\mathrm{PV}}{\mathrm{N}}$

$$\therefore \quad \mathrm{N} = \frac{3}{2} \times \frac{\mathrm{PV}}{(\text{ K.E./molecule })}$$
$$= \frac{3}{2} \times \frac{2 \times 10^5 \times 500 \times 10^{-6}}{6 \times 10^{-21}} = 2.5 \times 10^{22}$$

Question244

A gas at N.T.P. is suddenly compressed to onefourth of its original volume. If $\gamma = 1.5$, then the final pressure is

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Options:

A. 4 times

B. 1.5 times

C. 8 times

D. $\frac{1}{4}$ times

Answer: C

Solution:

As the change is sudden, the process is adiabatic

$$\therefore \quad P_1 V_1^\gamma = P_2 V_2^\gamma$$
$$\therefore \quad \frac{P_2}{P_1} = \left[\frac{V_1}{V_2}\right]^\gamma = \left[\frac{4}{1}\right]^{3/2} = \frac{8}{1}$$

Question245

A gas is compressed at a constant pressure of $50\ \mathrm{N/m^2}$ from a volume of $10\ \mathrm{m^3}$ to a volume of $4\ \mathrm{m^3}$. Energy of $100\ \mathrm{J}$ is then added to the gas by heating. Its internal energy is

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Options:

A. increased by 400 J

B. increased by 200 J

C. increased by 100 J

D. decreased by 200 J

Answer: A

Solution:

From first law of thermodynamics,

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

Change in volume due to compression

$\Delta V = V_2 - V_1 = 4 - 10 = -6m^3$

Negative sign indicates gas is compressed.

$\therefore \quad \Delta U = Q - P\Delta V = 100 - [50 \times (-6)] = 400 \text{ J}$

As, ΔU is positive, the internal energy is increased.

Question246

The pressure exerted by an ideal gas at a particular temperature is directly proportional to

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Options:

A. the mean speed of the gas molecules.

B. mean of the square of the speed of the gas molecules.

C. the square of the mean speed of the gas molecules.

D. the root mean square speed of the gas molecules.

Answer: B

Solution:

✅ Correct Answer: B. mean of the square of the speed of the gas molecules.

✔ **Explanation**

For an **ideal gas**, pressure arises due to the **collisions of gas molecules with the walls of the container.**

From the **kinetic theory of gases**, pressure is given by:

$$p = \frac{1}{3}\rho\overline{c^2}$$

Where:

- p = pressure
- ρ = density of gas
- $\overline{c^2}$ = **mean of the square of molecular speeds** (also called **mean square speed**)

This shows:

$$p \propto \overline{c^2}$$

So, pressure depends directly on the **mean of the square of molecular speeds**, not just the speed itself.

Question247

The side of a copper cube is $1 \mathrm{~m}$ at $0^{\circ} \mathrm{C}$. What will be the change in its volume, when it is heated to $100^{\circ} \mathrm{C}$? $\left[\alpha_{\text {copper }} \quad=18 \times 10^{-6} /{ }^{\circ} \mathrm{C}\right]$

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Options:

A. $45 \times 10^{-4} \mathrm{~m}^3$

B. $54 \times 10^{-4} \mathrm{~m}^3$

C. $34 \times 10^{-4} \mathrm{~m}^3$

D. $64 \times 10^{-4} \mathrm{~m}^3$

Answer: B

Solution:

The side length of a copper cube is 1 m at $0^{\circ}C$. We need to determine the change in its volume when it is heated to $100^{\circ}C$. Given the coefficient of linear expansion for copper $(\alpha_{\text{copper}}) = 18 \times 10^{-6}/^{\circ}C$, we use the volumetric expansion formula for a cube:

$\Delta V = V \cdot 3\alpha \cdot \Delta T$

Insert the given values:

$\Delta V = 3 \times 18 \times 10^{-6} \times 100$

This simplifies to:

$\Delta V = 54 \times 10^{-4}\,\text{m}^3$

Question248

The temperature of an ideal gas is increased from $27^{\circ}C$ to $927^{\circ}C$. The r.m.s. speed of its molecules becomes

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Options:

A. twice

B. four times.

C. half.

D. one-fourth.

Answer: A

Solution:

✔ Explanation

The formula for **root mean square (r.m.s.) speed** of gas molecules is:

$$v_{rms} \propto \sqrt{T}$$

So, if temperature changes, r.m.s. speed changes as the **square root of temperature.**

✔ Step 1: Convert temperatures to Kelvin

Given:

- Initial temperature = $27^{\circ}C = 300\ K$
- Final temperature = $927^{\circ}C = 1200\ K$

✔ Step 2: Use ratio

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{1200}{300}} = \sqrt{4} = 2$$

So, the r.m.s. speed becomes **twice**.

✔ Final Answer:

$$\boxed{\text{A. twice}}$$

Question249

A jar 'P' is filled with gas having pressure, volume and temperature $\mathrm{P}, \mathrm{V}, \mathrm{T}$ respectively. Another gas jar Q filled with a gas having pressure $2\mathrm{P}$, volume $\frac{\mathrm{V}}{4}$ and temperature $2\ \mathrm{T}$. The ratio of the number of molecules in jar P to those in jar Q is

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Options:

A. 1 : 1

B. 1 : 2

C. 2 : 1

D. 4 : 1

Answer: D

Solution:

According to the ideal gas equation $\mathrm{PV} = \mathrm{N k_B T}$

For jar P, we have

$\mathrm{PV} = \mathrm{N_1 k_B T}$ ..... (i)

For jar Q, we have,

$(2\mathrm{P})\left(\frac{V}{4}\right) = \mathrm{N_2 k_B (2\ T)}$

$\Rightarrow \mathrm{PV} = 4\ \mathrm{N_2 k_B T}$ ..... (ii)

From equations (i) and (ii)

$$N_1 = 4N_2 \quad \Rightarrow \frac{N_1}{N_2} = 4$$
$$\therefore \quad N_1 : N_2 = 4 : 1$$

Question250

For a gas having 'X' degrees of freedom, 'γ' is (γ = ratio of specific heats = $\mathrm{C_P/C_V}$)

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Options:

A. $\frac{1+X}{2}$

B. $1 + \frac{X}{2}$

C. $1 + \frac{2}{x}$

D. $1 + \frac{1}{x}$

Answer: C

Solution:

γ and degrees of freedom is related by

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

Where f is the number of degrees of freedoms.

Given $f = X$,

$\therefore \quad \gamma = \frac{X+2}{X} = 1 + \frac{2}{X}$

Question251

Two uniform brass rods A and B of length 'l' and '$2l$' and their radii '$2r$' and 'r' respectively are heated to same temperature. The ratio of the increase in the volume of rod A to that of rod B is

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Options:

A. 1 : 1

B. 1 : 2

C. 2 : 1

D. 1 : 4

Answer: C

Solution:

To determine the ratio of the increase in the volume of rod A to that of rod B, we need to consider the formula for the volumetric expansion due to heating. The change in volume (ΔV) of a rod due to a change in temperature can be given by:

$\Delta V = \beta V \Delta T$

where:

β = coefficient of volumetric expansion (which is the same for both rods since they are made of brass),

V = initial volume of the rod,

ΔT = change in temperature (which is the same for both rods).

First, let's calculate the volume of each rod. The volume V of a cylindrical rod is:

$V=\pi r^2 l$

For rod A:

Length = l,

Radius = $2r$.

Therefore, the initial volume of rod A (V_A) is:

$V_A=\pi(2r)^2 l=\pi \cdot 4r^2 \cdot l=4\pi r^2 l$

For rod B:

Length = $2l$,

Radius = r.

Therefore, the initial volume of rod B (V_B) is:

$V_B=\pi r^2(2l)=2\pi r^2 l$

Now, the increase in volume (ΔV) of each rod due to heating is given by:

For rod A:

$\Delta V_A=\beta V_A \Delta T=\beta(4\pi r^2 l)\Delta T=4\beta\pi r^2 l\Delta T$

For rod B:

$\Delta V_B=\beta V_B \Delta T=\beta(2\pi r^2 l)\Delta T=2\beta\pi r^2 l\Delta T$

To find the ratio of the increase in the volume of rod A to that of rod B, we take:

$\frac{\Delta V_A}{\Delta V_B}=\frac{4\beta\pi r^2 l\Delta T}{2\beta\pi r^2 l\Delta T}=\frac{4}{2}=2$

Thus, the ratio of the increase in volume of rod A to that of rod B is: **2:1**.

Therefore, the correct option is **Option C: 2:1**.

Question252

A gas at N.T.P. is suddenly compressed to $\left(\frac{1}{4}\right)^{\text{th}}$ of its original volume. The final pressure in (Given $\gamma=$ ratio of sp. heats $=\frac{3}{2}$) atmosphere is ($\mathrm{P}=$ original pressure)

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Options:

A. 4P

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

C. 8P

D. $\frac{1}{4}$P

Answer: C

Solution:

In Adiabatic compression,

$PV^{\gamma} = \text{constant}$

Given $V_{\text{new}} = \frac{1}{4}V$ and $\gamma = \frac{3}{2}$

$\therefore \quad \frac{P_{\text{new}}}{P} = \left(\frac{V}{V_{\text{new}}}\right)^{\gamma} = \left(\frac{V}{\frac{1}{4}V}\right)^{3/2}$

$\therefore \quad P_{\text{new}} = 8P$

Question253

In a thermodynamic process, there is no exchange of heat between the system and surroundings. Then the thermodynamic process is

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Options:

A. isothermal

B. isobaric

C. isochoric

D. adiabatic

Answer: D

Solution:

✅ Correct Answer: D. adiabatic

✔ Explanation

A thermodynamic process **with no heat exchange** between system and surroundings has:

$$Q = 0$$

From the **first law of thermodynamics:**

$$\Delta U = Q - W$$

If $Q = 0$:

$$\Delta U = -W$$

This condition $Q = 0$ defines an **adiabatic process.**

Question254

According to kinetic theory of gases, which one of the following statements is wrong?

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Options:

A. All the molecules of a gas are identical.

B. Collisions between the molecules of a gas and that of the molecules with the walls of the container are perfectly elastic.

C. The molecules do not exert appreciable force on one another except during collision.

D. The pressure exerted by a gas is due to the collision between the molecules of the gas.

Answer: D

Solution:

Answer: **(D) The pressure exerted by a gas is due to the collision between the molecules of the gas.**

The kinetic theory of gases is based on several postulates, which describe the behavior of an ideal gas.

Postulate A: All molecules of a specific gas are identical in mass and size. This is a correct postulate.

Postulate B: Collisions between molecules and between molecules and container walls are perfectly elastic, meaning kinetic energy is conserved. This is also a correct postulate.

Postulate C: Molecules are assumed to be point masses and do not exert attractive or repulsive forces on one another except during the brief moment of collision. This is a correct postulate.

Postulate D: The pressure exerted by a gas is due to the force of the molecules colliding with the **walls of the container**, not with each other. Collisions between molecules only transfer energy between them. Therefore, statement D is the wrong statement.

Question255

Three discs x, y and z having radii $2 \mathrm{~m}, 3 \mathrm{~m}$ and $6 \mathrm{~m}$ respectively are coated on outer surfaces. The wavelength corresponding to maximum intensity are $300 \mathrm{~nm}, 400 \mathrm{~nm}$ and $500 \mathrm{~nm}$ respectively. If $\mathrm{P}_{\mathrm{x}}, \mathrm{P}_{\mathrm{y}}$ and P_{z} are power radiated by them respectively then

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Options:

A. P_{X} is maximum

B. P_{Z} is maximum

C. P_{y} is maximum

D. $\mathrm{P}_{\mathrm{x}}=\mathrm{P}_{\mathrm{y}}=\mathrm{P}_{\mathrm{z}}$

Answer: B

Solution:

According to Wien's law, $\lambda_{\mathrm{m}} \mathrm{T}=$ constant (b)

$\therefore \mathrm{T}=\frac{\mathrm{b}}{\lambda_{\mathrm{m}}}$ ..... (1)

and from Stefan's law, $\mathrm{Q}=\sigma \mathrm{AT}^4$ .... (2)

For the disc, area $(\mathrm{A})=\pi \mathrm{r}^2$

$\therefore$ From (1) and (2),

$\mathrm{Q}=\sigma \cdot \pi \mathrm{r}^2 \cdot \frac{\mathrm{b}^4}{\lambda_{\mathrm{m}}^4}=\frac{\mathrm{Kr}^2}{(\lambda \mathrm{m})^4}$

where $\mathrm{K}=\pi \sigma \mathrm{b}^4$ is a constant

Q is the quantity of heat radiated per second or power.

Hence $\mathrm{P}_{\mathrm{x}}, \mathrm{P}_{\mathrm{y}}$ and P_{z} are the powers of x, y, z.

For x we have $\mathrm{r}_1=2 \mathrm{~m}$ and $\lambda_1=300 \mathrm{~nm}$

For y, we have $r_2=3 \mathrm{~m}$ and $\lambda_2=400 \mathrm{~nm}$

and For z, we have $\mathrm{r}_3=6 \mathrm{~m}$ and $\lambda_3=500 \mathrm{~nm}$

$$
\begin{aligned}
\therefore \mathrm{P}_{\mathrm{x}} & \propto \frac{\mathrm{r}_1^2}{\lambda_1^4} \text { or } \frac{2^2}{\left(3 \times 10^{-7}\right)^4} \text { or } \frac{4 \times 10^{+28}}{81} \\
\mathrm{P}_{\mathrm{y}} & \propto \frac{\mathrm{r}_2^2}{\lambda_2^4} \text { or } \frac{9 \times 10^{+28}}{256} \\
\mathrm{P}_{\mathrm{z}} & \propto \frac{\mathrm{r}_3^2}{\lambda_3^4} \text { or } \frac{36 \times 10^{28}}{625}
\end{aligned}
$$

But $\frac{4}{81}=0.049, \frac{9}{250}=0.035$ and $\frac{36}{625}=0.0576$

$\therefore \mathbf{P}_{\mathrm{z}}$ is maximum.

Question256

When the rms velocity of a gas is denoted by 'v', which one of the following relations is true?

($\mathrm{T}=$ Absolute temperature of the gas.)

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Options:

A. $\frac{\mathrm{v}^2}{\mathrm{~T}}=$ constant

B. $\mathrm{v}^2 \mathrm{~T}=$ constant

C. $\mathrm{vT}^2=$ constant

D. $\frac{\mathrm{v}}{\mathrm{T}^2}=$ constant

Answer: A

Solution:

The r.m.s. speed (v) of a gas is $v=\sqrt{\frac{3 R T}{M}}$ i.e. $\mathrm{v} \propto \sqrt{\mathrm{T}}$

$\therefore \mathrm{v}^2 \propto \mathrm{T} \quad \therefore \mathrm{v}^2=\mathrm{KT}$ or $\frac{\mathrm{v}^2}{\mathrm{T}}=$ constant

----

Question257

A monoatomic gas $\left(\gamma=\frac{5}{3}\right)$ initially at $27^{\circ} \mathrm{C}$ having volume 'V' is suddenly compressed to one-eighth of its original volume $\left(\frac{\mathrm{V}}{8}\right)$. After the compression its temperature becomes

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Options:

A. 580 K

B. 1200 K

C. 1160 K

D. 927 K

Answer: B

Solution:

For adiabatic charge, $\mathrm{PV}^\gamma=$ constant as well as $\mathrm{TV}^{\gamma-1}=$ constant and for a monoatomic gas $\gamma=\frac{5}{3}$

$$\therefore \mathrm{T}_1 \mathrm{~V}_1^{\gamma-1}=\mathrm{T}_2 \mathrm{~V}_2^{\gamma-1}$$
$$\therefore \frac{\mathrm{T}_2}{\mathrm{~T}_1}=\left(\frac{\mathrm{V}_1}{\mathrm{~V}_2}\right)^{\gamma-1}=\left(\frac{\mathrm{V}}{\mathrm{V} / 8}\right)^{5 / 3-1}$$

$\therefore \frac{T_2}{T_1} = (8)^{2/3} = (2^3)^{2/3} = 4$

$\therefore T_2 = 4\,T_1$ but $T_1 = 273 + 27 = 300$ K

$\therefore T_2 = 4 \times 300 = 1200$ K

Question258

Two monatomic ideal gases A and B of molecular masses 'm_1' and 'm_2' respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas A to that in gas B is given by

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Options:

A. $\sqrt{\frac{m_2}{m_1}}$

B. $\frac{m_1}{m_2}$

C. $\sqrt{\frac{m_1}{m_2}}$

D. $\frac{m_2}{m_1}$

Answer: A

Solution:

$v = \sqrt{\frac{3RT}{M}}$ or $v \propto \sqrt{\frac{1}{M}}$ at constant T

$\therefore \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$

Question259

The thermodynamic process in which no work is done on or by the gas is

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Options:

A. isochoric process

B. adiabatic process

C. isothermal process

D. isobaric process

Answer: A

Solution:

The thermodynamic process, in which no work is done on or by the system is isochoric process.

In an isochoric process, $V = \text{constant} \quad \therefore dV = 0$

$\therefore \text{Work done } (dW) = PdV = 0$

Note : $dQ = 0$ in adiabatic, $dT = 0$ in isothermal.

In isochoric, $dV = 0$ and in isobaric, $dP = 0$

Question260

Heat given to a body, which raises its temperature by 1°C is known as

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Options:

A. specific heat

B. thermal capacity

C. water equivalent

D. temperature gradient

Answer: B

Solution:

The heat given to a body, which raises its temperature by 1ºC (or 1 K), is known as the **thermal capacity** or sometimes referred to as the heat capacity of the body. The correct answer is Option B: thermal capacity.

The thermal capacity (C) of a body is defined as the amount of heat energy (Q) required to raise the temperature of the entire body by one degree Celsius (or one Kelvin). The formula for thermal capacity is given by:

$C = \frac{Q}{\Delta T}$

where **Q** is the heat energy supplied to the body and **ΔT** is the change in temperature.

To elaborate on the other options provided:

Option A: **Specific heat** (sometimes called specific heat capacity) is the amount of heat required to raise the temperature of one kilogram of the substance by one degree Celsius (or one Kelvin). It is an intrinsic property of the substance and is expressed in units such as joules per kilogram Kelvin (J/kg·K). The formula for specific heat (c) is given by:

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

where **m** is the mass of the substance.

Option C: **Water equivalent** is a somewhat outdated term used to describe a quantity of a substance that would absorb the same amount of heat as a given mass of water. It is based on the high specific heat capacity of water, which has historically been used as a benchmark. It's not precisely a term for the heat to raise the temperature but rather a comparative metric.

Option D: **Temperature gradient** refers to the rate of change of temperature with respect to distance in a particular direction. It is a vector quantity that illustrates how temperature changes from one point to another and is not related to the amount of heat energy that is supplied to a body. Therefore, it does not describe the amount of heat needed to increase the temperature of a body by 1ºC.

Question261

Which one of the following is NOT a correct expression for an ideal gas?

[C_p = Molar specific heat of a gas at constant pressure,

C_v = Molar specific heat of a gas at constant volume,

Y = Ratio of two specific heats of a gas,

R = **Universal gas constant]**

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Options:

A. $C_v = C_p + R$

B. $R = C_v(\gamma - 1)$

C. $\frac{C_v}{\mathrm{C_p}} = \frac{1}{\gamma}$

D. $R = \frac{C_\mathrm{p}(\gamma - 1)}{\gamma}$

Answer: A

Solution:

To determine which of the expressions given for an ideal gas is NOT correct, we need to recall some fundamental relationships between the specific heats and the gas constant for an ideal gas.

For an ideal gas, the following relationships hold:

1. $\mathrm{C_p - C_v = R}$

2. $\gamma = \frac{\mathrm{C_p}}{\mathrm{C_v}}$

3. $\mathrm{R = C_v(\gamma - 1)}$

4. $\mathrm{C_v} = \frac{\mathrm{R}}{\gamma - 1}$

Let's analyze each option:

- Option A: $\mathrm{C_v = C_p + R}$

This is incorrect because according to the first relationship, $\mathrm{R = C_p - C_v}$, and therefore, $\mathrm{C_v}$ cannot be greater than $\mathrm{C_p}$.

- Option B: $\mathrm{R = C_v(\gamma - 1)}$

This is correct as it matches the third relationship.

- Option C: $\frac{\mathrm{C_v}}{\mathrm{C_p}} = \frac{1}{\gamma}$

This is correct since $\gamma = \frac{\mathrm{C_p}}{\mathrm{C_v}}$ therefore, $\frac{\mathrm{C_v}}{\mathrm{C_p}} = \frac{1}{\gamma}$.

- Option D: $R = \frac{\mathrm{C_p}(\gamma - 1)}{\gamma}$

This can be derived from the given relationships. By substituting $\mathrm{C_v} = \frac{\mathrm{C_p}}{\gamma}$ into $\mathrm{R} = \mathrm{C_v}(\gamma - 1)$, we get $R = \frac{\mathrm{C_p}}{\gamma}(\gamma - 1) = \frac{\mathrm{C_p}(\gamma-1)}{\gamma}$ so this is correct.

Therefore, the incorrect expression is:

Option A: $C_v = C_p + R$

Question262

The molecular masses of helium and oxygen are 4 and 32 respectively. The ratio of r.m.s. speed of helium at 327° to r.m.s. speed of oxygen at 27° will be

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Options:

A. 1 : 6

B. 8 : 1

C. 1 : 8

D. 4 : 1

Answer: D

Solution:

The root mean square (r.m.s) speed of a gas is given by the equation:

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

where:

- v_{rms} is the root mean square speed.
- k is the Boltzmann constant.
- T is the temperature in Kelvin.
- m is the molecular mass in kg.

Let's denote the molecular masses by $m_H = 4\,\mathrm{u}$ for Helium and $m_O = 32\,\mathrm{u}$ for Oxygen. Also, convert the temperatures from Celsius to Kelvin:

$$T_1 = 327^\circ\mathrm{C} + 273 = 600\,\mathrm{K}$$

$T_2 = 27°C + 273 = 300\,\text{K}$

We need to find the ratio of r.m.s. speed of helium at 327°C to the r.m.s. speed of oxygen at 27°C:

$$\frac{v_{rms,He}}{v_{rms,O_2}}$$

Using the r.m.s. speed formula, we have:

$$v_{rms,He} = \sqrt{\frac{3k \cdot 600}{4}}$$

$$v_{rms,O_2} = \sqrt{\frac{3k \cdot 300}{32}}$$

We take the ratio:

$$\frac{v_{rms,He}}{v_{rms,O_2}} = \frac{\sqrt{\frac{3k \cdot 600}{4}}}{\sqrt{\frac{3k \cdot 300}{32}}}$$

Simplify the expression:

$$\frac{v_{rms,He}}{v_{rms,O_2}} = \sqrt{\frac{600}{4}} \div \sqrt{\frac{300}{32}} = \frac{\sqrt{600/4}}{\sqrt{300/32}}$$

Further simplify this expression:

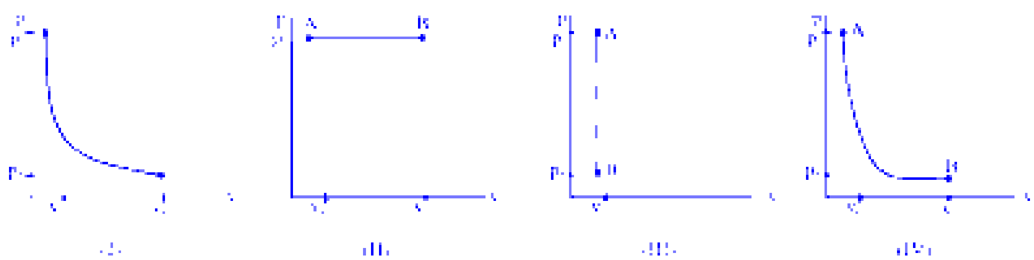
$$\frac{v_{rms,He}}{v_{rms,O_2}} = \sqrt{\frac{600}{4} \times \frac{32}{300}} = \sqrt{\frac{600 \cdot 32}{4 \cdot 300}} = \sqrt{\frac{19200}{1200}} = \sqrt{16} = 4$$

Thus, the ratio of the r.m.s. speed of helium to the r.m.s. speed of oxygen is 4:1. The correct option is:

Option D: 4 : 1

Question263

Which one of the following p-V diagram is correct for an isochoric process:



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Options:

A. IV

B. II

C. III

D. I

Answer: C

Solution:

✅ Correct Answer: III

✔ **Explanation**

An **isochoric process** is a thermodynamic process in which:

$$\Delta V = 0 \quad \text{(volume is constant)}$$

So in a **p–V diagram**, an isochoric process must be drawn as a **vertical line**, because:

- Volume remains constant (same value on x-axis)
- Pressure changes (moves up or down on y-axis)

Question264

Assume that for solar radiation, surface temperature of the sun is $6000 \mathrm{~K}$. If Wien's constant 'b' is $2.897 \times 10^{-3} \mathrm{~mK}$, the value of maximum wavelength will be

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Options:

A. $4828 \stackrel{o}{A}$

B. $3648 \stackrel{o}{A}$

C. $6400\overset{o}{A}$

D. $5890\overset{o}{A}$

Answer: A

Solution:

To find the value of the maximum wavelength of solar radiation, we can use Wien's Displacement Law. Wien's Displacement Law states that the product of the wavelength at which the emission of a black body radiation spectrum is maximized ($\lambda_{\max}$) and the absolute temperature (T) of the black body is a constant. The law is mathematically represented as:

$\lambda_{\max} \times T = b$

Where:

$\lambda_{\max}$ is the wavelength corresponding to the peak emission

T is the absolute temperature

b is Wien's constant

Given:

$T = 6000 \text{ K}$

$b = 2.897 \times 10^{-3} \text{ mK}$

Rearranging the formula to solve for $\lambda_{\max}$:

$\lambda_{\max} = \frac{b}{T}$

Substitute the given values into the equation:

$\lambda_{\max} = \frac{2.897 \times 10^{-3} \text{ mK}}{6000 \text{ K}}$

Calculate the value:

$\lambda_{\max} = \frac{2.897 \times 10^{-3}}{6000} \text{ m}$

$\lambda_{\max} = 4.828 \times 10^{-7} \text{ m}$

To convert meters to angstroms ($\overset{o}{A}$), note that:

$1 \text{ meter} = 10^{10}\overset{o}{A}$

Therefore:

$\lambda_{\max} = 4.828 \times 10^{-7} \text{ m} \times 10^{10}\overset{o}{A}$

$\lambda_{\max} = 4828\overset{o}{A}$

Therefore, the value of the maximum wavelength is $4828\overset{o}{A}$, and hence, the correct answer is:

Option A: $4828\overset{o}{A}$

Question265

A metal sphere cools at the rate of $1.5^{\circ}\mathrm{C}/\mathrm{min}$ when its temperature is $80^{\circ}\mathrm{C}$. At what rate will it cool when its temperature falls to $50^{\circ}\mathrm{C}$. [Temperature of surrounding is $30^{\circ}\mathrm{C}$]

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Options:

A. $0.9^{\circ}\mathrm{C}/\mathrm{min}$

B. $0.6^{\circ}\mathrm{C}/\mathrm{min}$

C. $1.5^{\circ}\mathrm{C}/\mathrm{min}$

D. $1.2^{\circ}\mathrm{C}/\mathrm{min}$

Answer: B

Solution:

When temperature is $80^{\circ}\mathrm{C}$, by Newton's law of cooling, we have

$1.5=\mathrm{k}\left(\frac{80+30}{2}-30\right)=\mathrm{k}(55-30)=25\ \mathrm{K}$

When temperature is $50^{\circ}\mathrm{C}$, let r be the rate of cooling.

Then

Then

$$r=k\left(\frac{50+30}{2}-30\right)=k(40-30)=10\ \mathrm{K}$$

$$\therefore \quad \frac{r}{1.5}=\frac{10}{25} \quad \therefore r=\frac{10}{25}\times 1.5=\frac{3}{5}=0.6^{\circ}\mathrm{C}/\mathrm{min}$$

Question266

A monoatomic gas is suddenly compressed to $(1/8)^{\text{th}}$ of its initial volume adiabatically. The ratio of the final pressure to initial pressure of the gas is $(\gamma = 5/3)$

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Options:

A. 32

B. 8

C. $\frac{40}{3}$

D. $\frac{24}{5}$

Answer: A

Solution:

For a monoatomic gas undergoing adiabatic compression, we use the adiabatic relation:

$P_1 V_1^\gamma = P_2 V_2^\gamma$

Given that the gas is compressed to $(1/8)$ of its initial volume, we have:

$V_2 = \frac{V_1}{8}$

We need to find the ratio of the final pressure (P_2) to the initial pressure (P_1). Substituting the volumes into the adiabatic relation, we get:

$P_1 V_1^\gamma = P_2 \left(\frac{V_1}{8}\right)^\gamma$

Let's solve for (P_2/P_1):

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

Since $(V_2 = V_1/8)$, we have:

$\frac{V_1}{V_2} = 8$

Therefore:

$P_2 = P_1 \cdot 8^\gamma$

Given $(\gamma = 5/3)$, we need to calculate (8^γ):

$8^{5/3} = (2^3)^{5/3} = 2^5 = 32$

Thus, the ratio of the final pressure to the initial pressure is:

$\frac{P_2}{P_1} = 32$

The correct answer is Option A: 32.

Question267

A monoatomic ideal gas initially at temperature T_1 is enclosed in a cylinder fitted with 8 frictionless piston. The gas is allowed to expand adiabatically to a temperature T_2 by releasing the piston suddenly. L_1 and L_2 are the lengths of the gas columns before and after the expansion respectively. Then $\frac{\mathrm{T}_2}{\mathrm{T}_1}$ is

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Options:

A. $\left(\frac{\mathrm{L}_2}{\mathrm{L}_1}\right)^{2/3}$

B. $\left(\frac{L_1}{L_2}\right)^{2/3}$

C. $\left(\frac{\mathrm{L}_1}{\mathrm{L}_2}\right)^{1/2}$

D. $\left(\frac{\mathrm{L}_2}{\mathrm{L}_1}\right)^{1/2}$

Answer: B

Solution:

For adiabatic expansion we have

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\therefore \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \left(\frac{L_1}{L_2}\right)^{\gamma-1} \quad [\because v \propto L]$$

$$= \left(\frac{L_1}{L_2}\right)^{\frac{5}{3}-1} \quad [\text{For monoatocomic gas } \gamma = \frac{5}{3}]$$

$$= \left(\frac{L_1}{L_2}\right)^{\frac{2}{3}}$$

Question268

For a monoatomic gas, the work done at constant pressure is 'W' The heat supplied at constant volume for the same rise in temperature of the gas is

$[\gamma = \frac{C_p}{C_v} = \frac{5}{2}$ for monoatomic gas]

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Options:

A. 2 W

B. W

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

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

Answer: D

Solution:

To determine the heat supplied at constant volume for a monoatomic gas, let's start by defining some fundamental relationships and properties of monoatomic gases.

The ratio of specific heats γ for a monoatomic gas is given as:

$\gamma = \frac{C_p}{C_v} = \frac{5}{3}$

Where:

- C_p: Specific heat at constant pressure
- C_v: Specific heat at constant volume

The work done at constant pressure, W, for a rise in temperature ΔT is defined as:

$W = P\Delta V$

Using the ideal gas law, $PV = nRT$, we know that at constant pressure, $V \propto T$, so:

$P\Delta V = nR\Delta T$

Thus, the work done at constant pressure can be written as:

$W = nR\Delta T$

The heat supplied at constant pressure Q_p is given by:

$Q_p = nC_p\Delta T$

Since the work done, W, at constant pressure is equivalent to $nR\Delta T$, it can also be related to Q_p using the specific heat at constant pressure:

$Q_p = W \cdot \frac{C_p}{R}$

The specific heat at constant volume, Q_v, is given by:

$Q_v = nC_v\Delta T$

Since $C_p/C_v = \gamma$:

$C_p = \gamma C_v$

Therefore, we can substitute to get:

$C_v = \frac{C_p}{\gamma}$

Substitute C_v into the expression for the heat supplied at constant volume:

$Q_v = n\left(\frac{C_p}{\gamma}\right)\Delta T$

Since $nR\Delta T = W$, and using the relationship between C_p and R for a monoatomic gas:

$C_p = \frac{\gamma R}{\gamma - 1}$

For a monoatomic gas, $\gamma = \frac{5}{3}$:

$C_p = \frac{\frac{5}{3}R}{\frac{5}{3}-1} = \frac{\frac{5}{3}R}{\frac{2}{3}} = \frac{5}{2}R$

Therefore, C_v is:

$C_v = \frac{C_p}{\gamma} = \frac{\frac{5}{2}R}{\frac{5}{3}} = \frac{3R}{2}$

Thus:

$Q_v = nC_v\Delta T = n\frac{3R}{2}\Delta T$

Since $W = nR\Delta T$, we can write:

$Q_v = \frac{3}{2} \cdot W$

Hence, the heat supplied at constant volume for the same rise in temperature of the gas is:

Option D: $\frac{3W}{2}$

Question269

An ideal gas with pressure P, volume V and temperature T is expanded isothermally to a volume $2\ \mathrm{V}$ and a final pressure $\mathrm{P_i}$. The same gas is expanded adiabatically to a volume $2\ \mathrm{V}$, the final pressure is $\mathrm{P_a}$. In terms of the ratio of the two specific heats for the gas 'γ', the ratio $\frac{P_i}{P_a}$ is

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Options:

A. $2^{\gamma+1}$

B. $2^{\gamma-1}$

C. $2^{1-\gamma}$

D. 2^{γ}

Answer: B

Solution:

For isothermal expansion we have

$$P_1V_1 = P_2V_2$$
$$\therefore \quad P_2 = P_1\frac{V_1}{V_2} = P_1 \times \frac{1}{2} = \frac{P}{2}$$
$$\therefore P_i = \frac{P}{2}$$

For adiabatic process :

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

$$\therefore \quad P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = P_1\left(\frac{1}{2}\right)^\gamma = \frac{P}{2^\gamma}$$

$$\therefore \quad P_a = \frac{P}{2^\gamma}$$

$$\therefore \quad \frac{P_i}{P_a} = \frac{2^\gamma}{2} = 2^{\gamma-1}$$

Question270

At what temperature does the average translational kinetic energy of a molecule in a gas becomes equal to kinetic energy of an electron accelerated from rest through potential difference of 'V' volt?

(N $=$ number of molecules, R $=$ gas constant, c $=$ electronic charge)

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Options:

A. $\frac{2\mathrm{eVN}}{3\mathrm{R}}$

B. $\frac{\mathrm{eVN}}{\mathrm{R}}$

C. $\frac{\mathrm{eVN}}{4\mathrm{R}}$

D. $\frac{3\mathrm{eVN}}{2\mathrm{R}}$

Answer: A

Solution:

To determine the temperature at which the average translational kinetic energy of a molecule in a gas becomes equal to the kinetic energy of an electron accelerated from rest through a potential difference of 'V' volts, we start by comparing their respective kinetic energies.

The kinetic energy of an electron accelerated through a potential difference V is given by:

$$E_{\text{electron}} = eV$$

where:

- e is the electronic charge.

- V is the potential difference in volts.

For a molecule in an ideal gas, the average translational kinetic energy is given by:

$E_{\text{translational}} \quad = \frac{3}{2} k_B T$

where:

- k_B is the Boltzmann constant.
- T is the absolute temperature in Kelvin.

Now, we equate the kinetic energy of the electron to the average translational kinetic energy of a molecule in the gas:

$eV = \frac{3}{2} k_B T$

Solving for temperature T, we get:

$T = \frac{2eV}{3k_B}$

For a gas with number of molecules N and using the relationship between Boltzmann constant k_B and gas constant R (i.e., $k_B = \frac{R}{N}$), we substitute this value into the equation:

$T = \frac{2eV}{3} \cdot \frac{N}{R}$

Simplifying, we obtain:

$T = \frac{2eVN}{3R}$

Thus, the correct option is:

Option A

$\frac{2\text{eVN}}{3\text{R}}$

Question271

The temperature difference between two sides of an iron plate, 1.8 cm thick is 9°C. Heat is transmitted through the plate $10\text{kcal}/\text{sm}^2$ at steady state. The thermal conductivity of iron is

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Options:

A. $0.02 \frac{\text{kcal}}{\text{ms}^\circ\text{C}}$

B. $0.04 \frac{\mathrm{kcal}}{\mathrm{ms}^{\circ} \mathrm{C}}$

C. $0.05 \frac{\mathrm{kcal}}{\mathrm{ms}^{\circ} \mathrm{C}}$

D. $0.004 \frac{\mathrm{kcal}}{\mathrm{ms}^{\circ}}$

Answer: A

Solution:

$$
\begin{aligned}
& \frac{Q}{A t}=\frac{k \Delta \theta}{d} \\
& \therefore 10=k \times \frac{9}{1.8 \times 10^{-2}} \\
& \therefore \quad k=\frac{18 \times 10^{-2}}{9}=2 \times 10^{-2} \mathrm{kcal} / \mathrm{mS}^{\circ} \mathrm{C}
\end{aligned}
$$

Question272

Internal energy of n_1 moles of hydrogen at temperature 'T' is equal to internal energy of 'n_2' moles of helium at temperature $2T$, then the ratio $\mathrm{n}_1 : \mathrm{n}_2$ is

[Degree of freedom of $\mathrm{He}=3$, Degree of freedom of $\mathrm{H}_2=5$]

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Options:

A. 5 : 3

B. 6 : 5

C. 2 : 3

D. 3 : 5

Answer: B

Solution:

The internal energy of an ideal gas is given by the following formula:

$U = \frac{f}{2} nRT$

where:

- U is the internal energy
- f is the degree of freedom
- n is the number of moles
- R is the ideal gas constant
- T is the temperature

We are given that the internal energy of n_1 moles of hydrogen at temperature T is equal to the internal energy of n_2 moles of helium at temperature $2T$. Therefore, we can write the following equation:

$\frac{5}{2} n_1 RT = \frac{3}{2} n_2 R(2T)$

Simplifying the equation, we get:

$5n_1 = 6n_2$

Therefore, the ratio $n_1 : n_2$ is $\boxed{6 : 5}$.

Question273

For an ideal gas, $R = \frac{2}{3} C_v$. This suggests that the gas consists of molecules, which are [R = universal gas constant]

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Options:

A. polyatomic

B. diatomic

C. monoatomic

D. a mixture of diatomic and polyatomic molecules

Answer: C

Solution:

For an ideal gas

$$R = C_p - C_v = \frac{2}{3} C_v$$
$$\therefore C_p = C_v + \frac{2}{3} C_v = \frac{5}{3} C_v$$
$$\therefore \frac{C_p}{C_v} = \frac{5}{3}$$

For a monoatomic gas $\gamma = \frac{C_p}{C_v} = \frac{5}{3}$

Question274

The rms speed of a gas molecule is 'V' at pressure 'P'. If the pressure is increased by two times, then the rms speed of the gas molecule at the same temperature will be

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Options:

A. V

B. $\sqrt{2}$ V

C. $\frac{V}{3}$

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

Answer: A

Solution:

The root mean square (rms) speed of gas molecules is given by the equation:

$V_{rms} = \sqrt{\frac{3k_B T}{m}}$

where:

V_{rms} = rms speed

k_B = Boltzmann constant

T = absolute temperature

m = mass of a gas molecule

It's important to note that the rms speed depends on the temperature and not directly on the pressure. As temperature remains constant in this problem (since it is specified "at the same temperature"), the rms speed of the gas molecule will not change when the pressure is increased.

As such, even if the pressure is increased by two times, the rms speed of the gas molecules will remain unchanged at the same temperature.

Hence, the correct option is:

Option A

V

Question275

Equal volumes of two gases, having their densíties in the ratio of $1:16$ exert equal pressures on the walls of two containers. The ratio of their rms speads $(\mathrm{C}_1:\mathrm{C}_2)$ is

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Options:

A. $1:4$

B. $4:1$

C. $8:1$

D. $1:8$

Answer: B

Solution:

To solve this problem, we need to understand that the root-mean-square (rms) speed of gas molecules is related to the temperature and the mass of the gas molecules. The formula for the rms speed of gas is given by:

$\mathrm{C}=\sqrt{\frac{3kT}{m}}$

where:

- C is the rms speed,
- k is the Boltzmann constant,

- T is the temperature, and
- m is the mass of the gas molecule.

We are given that the gases have equal volumes and exert equal pressures. From the ideal gas law:

$PV = nRT$

where P is the pressure, V is the volume, n is the number of moles, R is the ideal gas constant, and T is the temperature. If the pressures are equal and the volumes are equal, then it implies that the product nT must be the same for both gases.

In this problem, the temperatures are the same because the pressures and volumes are the same for both gases. Given that the densities are in the ratio $1 : 16$, we can write:

$\frac{\rho_1}{\rho_2} = \frac{1}{16}$

where $\rho = \frac{m}{V}$, and since the volumes are the same, the ratio of the masses of the individual molecules will be:

$\frac{m_1}{m_2} = \frac{1}{16}$

Now, substituting this ratio back into the rms speed formula, we have:

$\mathrm{C}_1 = \sqrt{\frac{3kT}{m_1}}$

$\mathrm{C}_2 = \sqrt{\frac{3kT}{m_2}}$

Thus, the ratio of their rms speeds is:

$\frac{\mathrm{C}_1}{\mathrm{C}_2} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{16}{1}} = 4$

Therefore, the ratio of the rms speeds is $4 : 1$.

The correct answer is **Option B: 4:1**.

Question276

A cylindrical rod has temperatures 'T_1' and 'T_2' at its ends. The rate of flow of heat is 'Q_1' cal s^{-1}. If length and radius of the rod are doubled keeping temperature constant, then the rate of flow of heat 'Q_2' will be

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Options:

A. $Q_2 = \frac{Q_1}{2}$

B. $Q_2 = \frac{Q_1}{4}$

C. $Q_2 = 4Q_1$

D. $Q_2 = 2Q_1$

Answer: D

Solution:

To find the rate of flow of heat Q_2 when both the length and radius of the cylindrical rod are doubled while keeping the temperatures T_1 and T_2 at its ends constant, we need to understand how thermal conductivity works in a cylindrical shape.

The heat flow rate through a cylindrical rod is given by Fourier's law of heat conduction:

$Q = \frac{KA(T_1 - T_2)}{L}$

where:

- Q is the rate of heat transfer
- K is the thermal conductivity of the material
- A is the cross-sectional area of the rod
- T_1 and T_2 are the temperatures at the ends of the rod
- L is the length of the rod

The cross-sectional area A of a cylindrical rod with radius r is given by:

$A = \pi r^2$

Now, suppose the initial length and radius of the rod are L and r, and this gives us the initial heat flow rate Q_1:

$Q_1 = \frac{K\pi r^2(T_1 - T_2)}{L}$

If both the length and radius of the rod are doubled, the new length becomes $2L$ and the new radius becomes $2r$. Hence, the new cross-sectional area A' of the rod becomes:

$A' = \pi(2r)^2 = 4\pi r^2$

Substituting these into the heat flow equation, we get the new heat flow rate Q_2:

$Q_2 = \frac{KA'(T_1 - T_2)}{2L}$

$Q_2 = \frac{K(4\pi r^2)(T_1 - T_2)}{2L}$

$Q_2 = 2\frac{K\pi r^2(T_1 - T_2)}{L}$

$Q_2 = 2Q_1$

Thus, the rate of flow of heat Q_2 when the length and radius of the rod are doubled is:

$Q_2 = 2Q_1$

Therefore, the correct answer is:

Option D: $Q_2 = 2Q_1$

Question277

The initial pressure and volume of a gas is 'P' and 'V' respectively. First by isothermal process gas is expanded to volume '9 V' and then by adiabatic process its volume is compressed to 'V' then its final pressure is (Ratio of specific heat at constant pressure to constant volume $= \frac{3}{2}$)

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Options:

A. 6 P

B. 27 P

C. 3 P

D. 9 P

Answer: C

Solution:

To determine the final pressure of the gas after undergoing an isothermal expansion followed by an adiabatic compression, let's break down the problem step-by-step.

Step 1: Isothermal Expansion

During an isothermal process, the temperature remains constant. For an ideal gas, the relationship between pressure and volume is given by:

$P_1V_1 = P_2V_2$

Here, the initial pressure is P and the initial volume is V. After the isothermal expansion, the volume becomes 9 V and the pressure becomes P_2.

So we have:

$P \cdot V = P_2 \cdot 9V$

Solving for P_2:

$$P_2 = \frac{P}{9}$$

Step 2: Adiabatic Compression

During an adiabatic process, no heat is exchanged with the surroundings. The relationship between pressure and volume for an adiabatic process is given by:

$$P_2 V_2^{\gamma} = P_3 V_3^{\gamma}$$

Here, γ is the adiabatic index, which is the ratio of specific heat at constant pressure to constant volume ($= \frac{3}{2} = 1.5$). The final volume V_3 is equal to the initial volume V.

Given:

$$P_2 = \frac{P}{9}, \quad V_2 = 9V, \quad V_3 = V$$

Thus, we have:

$$\left(\frac{P}{9}\right) \cdot (9V)^{\gamma} = P_3 \cdot V^{\gamma}$$

Substituting $\gamma = 1.5$:

$$\left(\frac{P}{9}\right) \cdot (9V)^{1.5} = P_3 \cdot V^{1.5}$$

Since $\gamma = 1.5$, we have:

$$(9V)^{1.5} = 9^{1.5} \cdot V^{1.5} = 27 \cdot V^{1.5}$$

Thus:

$$\left(\frac{P}{9}\right) \cdot 27 \cdot V^{1.5} = P_3 \cdot V^{1.5}$$

Dividing both sides by $V^{1.5}$:

$$\left(\frac{P}{9}\right) \cdot 27 = P_3$$

Simplifying, we get:

$$P_3 = 3P$$

So, the final pressure of the gas after the adiabatic compression is **3P**.

Therefore, the correct answer is:

Option C: 3 P

Question278

If m' represents the mass of each molecules of a gas and T' its absolute temperature then the root mean square speed of the gas molecule is proportional to

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Options:

A. $\mathrm{m}^{-\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}$

B. mT

C. $\mathrm{m}^{\frac{1}{2}}\mathrm{T}^{-\frac{1}{2}}$

D. $\mathrm{m}^{\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}$

Answer: A

Solution:

The root mean square (rms) speed of gas molecules is a measure of the speed of particles in a gas and is given by the following formula:

$$v_{\text{rms}} = \sqrt{\frac{3k_BT}{m}}$$

where:

- v_{rms} is the root mean square speed
- k_B is the Boltzmann constant
- T is the absolute temperature
- m is the mass of a gas molecule

In order to find how the rms speed is proportional to the mass of each molecule m' and the absolute temperature T", we can analyze the proportionality directly from the equation given.

Rewriting the proportionality aspect of the equation:

$$v_{\text{rms}} \propto \sqrt{\frac{T}{m}}$$

This implies that:

$$v_{\text{rms}} \propto T^{\frac{1}{2}}m^{-\frac{1}{2}}$$

Thus, the root mean square speed of the gas molecule is proportional to

Option A: $\mathrm{m}^{-\frac{1}{2}}\mathrm{T}^{\frac{1}{2}}$

Question279

An ideal gas at pressure 'p' is adiabatically compressed so that its density becomes twice that of the initial. If $\gamma = \frac{c_p}{c_v} = \frac{7}{5}$, then final pressure of the gas is

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Options:

A. p

B. 2p

C. $\frac{7}{5}$p

D. 2.63p

Answer: D

Solution:

Here's how to solve this problem:

For an adiabatic process, we have the following relationship:

$p_1 V_1^\gamma = p_2 V_2^\gamma$

where:

* p_1 and V_1 are the initial pressure and volume.

* p_2 and V_2 are the final pressure and volume.

* γ is the adiabatic index (ratio of specific heats).

We're given that the density doubles. Density is mass per unit volume, so if the density doubles, the volume is halved. Therefore, $V_2 = \frac{1}{2} V_1$.

Substituting these values into the adiabatic equation:

$p_1 V_1^\gamma = p_2 \left(\frac{1}{2} V_1\right)^\gamma$

Simplifying:

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

Solving for p_2:

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

Substituting the given value of $\gamma = \frac{7}{5}$:

$p_2 = p_1 \times 2^{7/5} \approx p_1 \times 2.63$

Therefore, the final pressure of the gas is approximately **2.63p**. The correct answer is **Option D**.

Question280

Which one of the following statements is wrong for an isobaric process?

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Options:

A. The pressure of the system remains constant

B. There is change in volume, when work is done

C. Temperature of the system remains constant

D. Energy exchanged is used to do work to change internal energy

Answer: C

Solution:

An isobaric process is one in which the pressure remains constant as the system undergoes a change. Let's analyze the given options:

Option A: The pressure of the system remains constant

This statement is correct because, by definition, an isobaric process maintains a constant pressure.

Option B: There is change in volume, when work is done

This statement is also correct. In an isobaric process, the work done by the gas is the product of the pressure and the change in volume. This can be represented as:

$W = P\Delta V$

Option C: Temperature of the system remains constant

This statement is incorrect. In an isothermal process, the temperature remains constant, but in an isobaric process, it is not necessarily the case. The temperature can change even though the pressure remains constant. Therefore, this option is wrong for an isobaric process.

Option D: Energy exchanged is used to do work to change internal energy

This statement is correct. According to the first law of thermodynamics, the energy exchanged (heat energy) in an isobaric process is used to do work and change the internal energy of the system. The energy balance can be expressed as:

$Q = \Delta U + W$

where Q is the heat added to the system, ΔU is the change in internal energy, and W is the work done by the system.

In summary, Option C is the wrong statement for an isobaric process.

Question281

For a perfectly black body, coefficient of emission is

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Options:

A. zero

B. infinity

C. unity

D. less than one (non-zero)

Answer: C

Solution:

Coefficient of emission = coefficient of absorption

For a perfectly black body a = e = 1

Question282

Two rods of different metals have coefficients of linear expansion 'α_1' and 'α_2' respectvely. Their respective lengths are 'L_1' and 'L_2'. At all temperatures $(L_2 - L_1)$ is same. The correct relation is

Options:

A. $L_1\alpha_1^2 = L_2\alpha_2^2$

B. $L_1^2\alpha_1^2 = L_2^2\alpha_2^2$

C. $L_1\alpha_2 = L_2\alpha_1$

D. $L_1\alpha_1 = L_2\alpha_2$

Answer: D

Solution:

To solve this problem, we need to understand the relationship between the coefficients of linear expansion, initial lengths, and the condition given that $(L_2 - L_1)$ is the same at all temperatures.

Linear expansion can be described by the formula for the change in length, ΔL, which is proportional to the initial length L and the change in temperature ΔT. For a given material, this can be written as:

$\Delta L_1 = L_1\alpha_1\Delta T$

$\Delta L_2 = L_2\alpha_2\Delta T$

Given that $(L_2 - L_1)$ is the same at all temperatures, the difference in the change in lengths due to temperature changes should also be equal at all temperatures. This implies:

$\Delta L_2 - \Delta L_1 = 0$

Substitute the expressions for ΔL_1 and ΔL_2:

$L_2\alpha_2\Delta T - L_1\alpha_1\Delta T = 0$

Since ΔT is common and non-zero, we can divide both sides by ΔT:

$L_2\alpha_2 - L_1\alpha_1 = 0$

Therefore, the correct relation is:

$L_1\alpha_1 = L_2\alpha_2$

So the correct option is:

Option D

Question283

The temperature of a black body is increased by 50%, then the percentage increase in the rate of radiation by the body is approximated

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Options:

A. 50%

B. 100%

C. 400%

D. 150%

Answer: C

Solution:

Rate of radiation $\mathrm{R} \propto \mathrm{T}^4$

$$\therefore \frac{R_2}{R_1}=\left(\frac{T_2}{T_1}\right)^4=(1.5)^4 \approx 5$$
$$\therefore R_2=5 R_1$$
$$R_2-R_1=4 R_1$$
$$\frac{\mathrm{R}_2-\mathrm{R}_1}{\mathrm{R}_1}=4$$

Percentage increase $=\left(\frac{R_2-R_1}{R_1}\right) \times 100=400\%$

Question284

The emissive power of sphere of area $0.04 \mathrm{~m}^2$ is $0.7 \mathrm{~k} \mathrm{~cal} \mathrm{~s}^{-1} \mathrm{~m}^{-2}$. The amount of heat radiated in 20 second is

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Options:

A. $2.8 \mathrm{~k} \mathrm{cal} \mathrm{~s}^{-1} \mathrm{~m}^{-2}$

B. $0.28 \mathrm{~k} \mathrm{cal} \mathrm{~s}^{-1} \mathrm{~m}^{-2}$

C. $5.6 \mathrm{~k} \mathrm{cal} \mathrm{~s}^{-1} \mathrm{~m}^{-2}$

D. $0.56 \mathrm{~k} \mathrm{cal} \mathrm{~s}^{-1} \mathrm{~m}^{-2}$

Answer: D

Solution:

The amount of heat radiated by an object is given by the formula:

$Q=E \times A \times t$

where:

- Q is the amount of heat radiated,
- E is the emissive power (in $kcal\ s^{-1}\ m^{-2}$),
- A is the surface area (in m^2), and
- t is the time in seconds.

Given that:

- Emissive power, $E=0.7\ kcal\ s^{-1}\ m^{-2}$
- Area, $A=0.04\ m^2$
- Time, $t=20\ s$

Substituting the given values into the formula gives:

$Q=0.7 \times 0.04 \times 20$

$Q=0.56\ kcal$

Hence, the amount of heat radiated in 20 seconds is 0.56 $k$cal, which corresponds to Option D.

Question285

The rate of flow of heat through a copper rod with temperature difference $28^{\circ} \mathrm{C}$ is $1400 \mathrm{~cal} \mathrm{~s}^{-1}$. The thermal resistance of copper rod will be

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Options:

A. $0.05 \frac{{}^{\circ}\mathrm{Cs}}{\mathrm{cal}}$

B. $0.02 \frac{{}^{\circ}\mathrm{Cs}}{\mathrm{cal}}$

C. $5 \frac{{}^{\circ}\mathrm{Cs}}{\mathrm{cal}}$

D. $2 \frac{{}^{\circ}\mathrm{Cs}}{\mathrm{cal}}$

Answer: B

Solution:

The thermal resistance R of a material is given by the ratio of the temperature difference (ΔT) across the material to the rate of heat flow (Q) through the material. Mathematically, this can be expressed as:

$R = \frac{\Delta T}{Q}$

For this particular problem, we are given:

- Temperature difference, $\Delta T = 28^{\circ}\mathrm{C}$
- Rate of heat flow, $Q = 1400 \text{ cal s}^{-1}$

Using the formula for thermal resistance, we can calculate R as follows:

$R = \frac{28^{\circ}\mathrm{C}}{1400 \text{ cal s}^{-1}}$

$R = 0.02 \frac{{}^{\circ}\mathrm{Cs}}{\mathrm{cal}}$

Therefore, the thermal resistance of the copper rod is $0.02 \frac{{}^{\circ}\mathrm{Cs}}{\mathrm{cal}}$. The correct answer is **Option B**.

Question286

The change in internal energy of the mass of a gas, when the volume changes from 'V' to '2 V' at constant pressure 'P' is (γ = Ratio of Cp to Cv)

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Options:

A. $\frac{\mathrm{PV}}{(\gamma-1)}$

B. $\frac{P}{(\gamma-1)}$

C. PV

D. $\frac{\gamma PV}{(\gamma-1)}$

Answer: A

Solution:

$$\begin{aligned} & \Delta U = nC_v\Delta T \\ & = n\frac{R}{\gamma-1}\Delta T \\ & = \frac{P\Delta V}{\gamma-1} = \frac{PV}{\gamma-1} \\ & \because \Delta V = 2V - V \end{aligned}$$

Question287

If the pressure of an ideal gas is decreased by 10% isothermally, then its volume will

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Options:

A. decrease by 8%

B. decrease by 9%

C. increase by 8%

D. increase by 11.1%

Answer: D

Solution:

For isothermal process, $P_1V_1 = P_2V_2$

$P_2 = P_1 - \frac{P_1}{10} = \frac{9}{10} P_1$

$$\therefore P_1 V_1 = \frac{9}{10} P_1 V_2$$

$$\therefore V_2 = \frac{10}{9} V_1$$

$$= 1.11 V_1$$

$$= V_1 + 0.11 V_1$$

Question288

An ideal gas having molar mass 'M_0', has r.m.s. velocity 'V' at temperature 'T'. Then

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Options:

A. $VT^2 =$ constant

B. $\frac{v^2}{T} =$ constant

C. $V^2T =$ constant

D. V is independent of T

Answer: B

Solution:

To solve this question, we need to recall the relationship between the root mean square (r.m.s.) velocity of an ideal gas, its temperature, and its molar mass. The r.m.s. velocity, V, of an ideal gas can be expressed using the equation:

$V = \sqrt{\frac{3RT}{M_0}}$

where:

- V is the root mean square velocity,
- R is the universal gas constant,
- T is the temperature in Kelvin,
- M_0 is the molar mass of the gas.

We must analyze each option in light of this equation.

Option A: $\mathrm{VT}^2=$ constant

We substitute the expression for V into this option:

$$\mathrm{VT}^2=\left(\sqrt{\frac{3RT}{M_0}}\right)T^2=\sqrt{\frac{3R}{M_0}}T^{2.5}$$

Here, we see that VT^2 is not a constant because it is proportional to $T^{2.5}$.

Option B: $\frac{\mathrm{v}^2}{\mathrm{T}}=$ constant

Notice that there's a typographic mistake in the question: it should probably refer to V^2 instead of v^2 for consistency. Correcting this and substituting the expression for V, we get:

$$\frac{V^2}{T}=\frac{\frac{3RT}{M_0}}{T}=\frac{3R}{M_0}$$

This expression clearly shows that $\frac{V^2}{T}$ is a constant, because it only depends on constants R and M_0, and does not change with temperature T.

Option C: $\mathrm{V}^2\mathrm{T}=$ constant

Substituting the expression for V gives:

$$V^2T=\left(\frac{3RT}{M_0}\right)T=\frac{3R}{M_0}T^2$$

Since this is proportional to T^2, it is not a constant relationship with respect to T.

Option D: V is independent of T

Given the formula $V=\sqrt{\frac{3RT}{M_0}}$, we see that V depends on T (temperature), so this option is incorrect.

Therefore, **Option B** is correct: $\frac{V^2}{T}$ is a constant.

Question289

An ideal gas at $27^{\circ}\mathrm{C}$ is compressed adiabatically to $(8/27)$ of its original volume. If ratio of specific heats, $\gamma=5/3$ then the rise in temperature of the gas is

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Options:

A. 500 K

B. 125 K

C. 250 K

D. 375 K

Answer: D

Solution:

For an adiabatic process $TV^{\gamma-1}$ = constant

$$\therefore \frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{\gamma-1}=\left(\frac{27}{8}\right)^{\frac{5}{3}-1}=\left(\frac{27}{8}\right)^{\frac{2}{3}}=\frac{9}{4}$$
$$\therefore T_2=\frac{4}{9}\cdot T_1=\frac{4}{9}\times 300=675\text{ K}$$
$$\therefore T_2-T_1=675-300=375\text{ K}$$

Question290

The translational kinetic energy of the molecules of a gas at absolute temperature (T) can be doubled

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Options:

A. by increasing T to 4 T

B. by increasing T to 2 T

C. by decreasing T to T/2

D. by increasing T to $\sqrt{2}$ T

Answer: B

Solution:

The correct answer is **Option B: by increasing T to 2T**. Here's why:

The translational kinetic energy (KE) of gas molecules is directly proportional to the absolute temperature (T). This relationship is described by the following equation:

$KE=\frac{3}{2}kT$

Where:

- KE is the translational kinetic energy
- k is the Boltzmann constant
- T is the absolute temperature in Kelvin

To double the translational kinetic energy, we need to double the absolute temperature. This means increasing T to 2T.

Let's analyze why the other options are incorrect:

- **Option A: Increasing T to 4T** would quadruple the translational kinetic energy, not double it.
- **Option C: Decreasing T to T/2** would halve the translational kinetic energy.
- **Option D: Increasing T to √2T** would increase the kinetic energy by a factor of √2, not double it.

Therefore, the only way to double the translational kinetic energy of gas molecules is to double the absolute temperature.

Question291

A polyatomic gas $(\gamma = 4/3)$ is compressed to $\left(\frac{1}{8}\right)^{\text{th}}$ of its volume adiabatically. If its initial pressure is P_0, its new pressure will be

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Options:

A. $2\mathrm{P}_0$

B. $8\mathrm{P}_0$

C. $6\mathrm{P}_0$

D. $16\mathrm{P}_0$

Answer: D

Solution:

For an adiabatic process, the following relation holds:

$P_1 V_1^\gamma = P_2 V_2^\gamma$

where:

- P_1 is the initial pressure

- V_1 is the initial volume
- P_2 is the final pressure
- V_2 is the final volume
- γ is the adiabatic index

In this case, we have:

- $P_1 = P_0$
- $V_1 = V$
- $V_2 = \frac{V}{8}$
- $\gamma = \frac{4}{3}$

Substituting these values into the adiabatic equation, we get:

$$P_0 V^{\frac{4}{3}} = P_2 \left(\frac{V}{8}\right)^{\frac{4}{3}}$$

Simplifying the equation:

$$P_0 V^{\frac{4}{3}} = P_2 \left(\frac{V^{\frac{4}{3}}}{8^{\frac{4}{3}}}\right)$$

$$P_0 V^{\frac{4}{3}} = P_2 \left(\frac{V^{\frac{4}{3}}}{16}\right)$$

$$P_2 = 16 P_0$$

Therefore, the new pressure is $16P_0$.

So the answer is **Option D:** $16P_0$.

Question292

If the temperature of the sun is doubled, the rate of energy received by the earth will be increased by a factor

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Options:

A. 8

B. 2

C. 4

D. 16

Answer: D

Solution:

To determine the factor by which the rate of energy received by the Earth will increase if the temperature of the Sun is doubled, we should consider the Stefan-Boltzmann law. The Stefan-Boltzmann law states that the power radiated per unit area of a black body is proportional to the fourth power of its absolute temperature. Mathematically, it is expressed as:

$E \propto T^4$

where E is the energy radiated per unit area and T is the absolute temperature.

If the original temperature of the Sun is T and the temperature is doubled to $2T$, then the new rate of energy radiated (E') can be calculated as follows:

$E' \propto (2T)^4$

Expanding this, we get:

$E' \propto 2^4 \cdot T^4$

Since $2^4 = 16$, we have:

$E' \propto 16 \cdot T^4$

This means the new rate of energy radiated by the Sun is 16 times the original rate of energy. Therefore, the rate of energy received by the Earth will be increased by a factor of 16.

The correct option is:

Option D: 16

Question293

Which of the following statements is true?

($\Delta \mathrm{U}=$ increase in internal energy, $\mathrm{dW}=$ work done by the system)

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Options:

A. In an adiabatic process $\Delta \mathrm{U}=\mathrm{dW}$

B. In an adiabatic process $\Delta \mathrm{U}=-\mathrm{dW}$

C. In an isothermal process $\Delta \mathrm{U}=-\mathrm{dW}$.

D. In an isothermal process $\Delta U = dW$

Answer: B

Solution:

In thermodynamics, understanding the relationships between internal energy, work, and heat for different types of processes is crucial. Let's analyze the options given:

First, let's recall the first law of thermodynamics, which states:

$\Delta U = Q - W$

Here:

ΔU = Change in internal energy

Q = Heat added to the system

W = Work done by the system

Now, let's consider each type of process:

Adiabatic Process: In an adiabatic process, no heat is exchanged with the surroundings, so $Q = 0$. This simplifies the first law of thermodynamics to:

$\Delta U = -W$

This means that the change in internal energy is equal to the negative of the work done by the system.

Therefore, the correct statement in the context of an adiabatic process is:

Option B: **In an adiabatic process** $\Delta U = -dW$

Isothermal Process: In an isothermal process, the temperature remains constant, which implies that there is no change in internal energy for an ideal gas. So:

$\Delta U = 0$

According to the first law of thermodynamics:

$0 = Q - W$

This simplifies to:

$Q = W$

Therefore, there is no direct relationship between ΔU and W in an isothermal process other than that $\Delta U = 0$.

So, options C and D are not correct regarding isothermal processes.

Conclusion: The correct answer is:

Option B: In an adiabatic process $\Delta U = -dW$

Question294

Let 'W$_1$' be the work done in blowing a soap bubble of radius 'r' from soap solution at room temperature. The soap solution is now heated and second soap bubble of radius '$2r$' is blown from the heated soap solution. If 'W_2' is the work done in forming this bubble then

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Options:

A. $\mathrm{W}_2=2 \mathrm{~W}_1$

B. $\mathrm{W}_2=4 \mathrm{~W}_1$

C. $\mathrm{W}_2>4 \mathrm{~W}_1$

D. $\mathrm{W}_2<4 \mathrm{~W}_1$

Answer: D

Solution:

$W_1=8 \pi r^2 T$

where $\mathrm{T}=$ surface tension

$\mathrm{W}_2=8 \pi(2 r)^2 \mathrm{~T}^{\prime}=32 \mathrm{r}^2 \mathrm{~T}^{\prime}$

Since soap solution is heated, its surface tension decreases.

$\therefore \mathrm{T}^{\prime}<\mathrm{T}$
$\therefore \mathrm{W}_2<4 \mathrm{~W}_1$ or $4 \mathrm{~W}_1>\mathrm{W}_2$

Question295

A cylindrical rod is having temperatures θ_1 and θ_2 at its ends. The rate of heat flow is 'Q' Js^{-1}. All the linear dimensions of the rod are doubled by keeping the temperatures constant. What is the new rate of flow of heat?

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Options:

A. $\frac{Q}{2}$

B. $\frac{Q}{4}$

C. 2Q

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

Answer: C

Solution:

To solve this problem, we need to understand how the rate of heat flow, Q, through a cylindrical rod changes when its linear dimensions are doubled. The rate of heat flow through a rod can be expressed using Fourier's law of heat conduction:

$Q = \frac{k \cdot A \cdot (\theta_1 - \theta_2)}{L}$

where:

- Q is the rate of heat flow.
- k is the thermal conductivity of the material.
- A is the cross-sectional area of the rod.
- θ_1 and θ_2 are the temperatures at the ends of the rod.
- L is the length of the rod.

When the linear dimensions of the rod are doubled, both the length and the cross-sectional area will change. Let's look at each dimension:

- If the original length is L, the new length will be $2L$.
- If the original cross-sectional area is A, the new cross-sectional area will be $4A$ (since doubling the diameter of a circle quadruples its area).

Substituting the new dimensions into the formula, we get the new rate of heat flow, Q':

$Q' = \frac{k \cdot 4A \cdot (\theta_1 - \theta_2)}{2L}$

Simplifying the equation:

$Q' = \frac{4 \cdot k \cdot A \cdot (\theta_1 - \theta_2)}{2L}$

We can further simplify this to:

$Q' = 2 \cdot \frac{k \cdot A \cdot (\theta_1 - \theta_2)}{L}$

Since $\frac{k \cdot A \cdot (\theta_1 - \theta_2)}{L}$ is the original rate of heat flow Q, we have:

$Q' = 2Q$

Therefore, the new rate of flow of heat is twice the original rate of flow. The correct answer is:

Option C 2Q

Question296

For a gas molecule with 6 degrees of freedom, which one of the following relation between gas constant 'R' and molar specific heat '$\mathrm{C_v}$' is correct?

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Options:

A. $R = \frac{C_v}{3}$

B. $\mathrm{R} = \frac{5\mathrm{C_v}}{4}$

C. $\mathrm{R} = \frac{\mathrm{C_v}}{2}$

D. $\mathrm{R} = \frac{3\mathrm{C_v}}{4}$

Answer: A

Solution:

To determine the correct relationship between the gas constant R and the molar specific heat at constant volume $\mathrm{C_v}$ for a gas molecule with 6 degrees of freedom, we can use the concepts from the kinetic theory of gases. For a gas molecule, the degrees of freedom (f) directly influence the molar specific heat capacities.

Firstly, let's recall the general relationship between the degrees of freedom (f), the molar specific heat at constant volume ($\mathrm{C_v}$), and the molar specific heat at constant pressure ($\mathrm{C_p}$):

$\mathrm{C_v} = \frac{f}{2}\mathrm{R}$

$\mathrm{C_p} = \mathrm{C_v} + \mathrm{R}$

For a gas molecule with 6 degrees of freedom:

$\mathrm{C_v} = \frac{6}{2}\mathrm{R} = 3\mathrm{R}$

Now substituting C_v in the first equation:

$3R = C_v$

Therefore, solving for R we get:

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

Given this derivation, the correct relation is **Option A**:

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

Question297

What is the ratio of the velocity of sound in hydrogen $\left(\gamma = \frac{7}{5}\right)$ to that in helium $\left(\gamma = \frac{5}{3}\right)$ at the same temperature? (Molecular weight of hydrogen and helium is 2 and 4 respectively.)

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Options:

A. $\frac{\sqrt{42}}{5}$

B. $\frac{5}{\sqrt{42}}$

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

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

Answer: A

Solution:

Velocity of sound is given by

$V = \sqrt{\frac{\gamma RT}{M}} \quad \therefore \frac{V_H}{V_{He}} = \sqrt{\frac{\gamma_H}{\gamma_{He}} \cdot \frac{M_{He}}{M_H}}$ (T is the same for both)

$= \sqrt{\frac{7}{5} \times \frac{3}{5} \times \frac{4}{2}} = \frac{\sqrt{42}}{5}$

Question298

Equal volumes of two gases are kept in different containers having densities in the ratio 1 : 16. They exert equal pressures on the wall of their respective containers. Then the ratio of their r.m.s. velocities is

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Options:

A. 16 : 1

B. 1 : 8

C. 4 : 1

D. 1 : 12

Answer: C

Solution:

Pressure $\mathrm{P}=\frac{1}{3} \rho \mathrm{c}^2 \quad \therefore \mathrm{c}=\sqrt{\frac{3 \mathrm{p}}{\rho}}$

$\therefore \quad \frac{C_1}{C_2}=\sqrt{\frac{\rho_2}{\rho_1}}=\sqrt{\frac{16}{1}}=4$

Question299

In thermodynamics, for an isochoric process, which one of the following statement is INCORRECT?

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Options:

A. Energy exchanged is used to do work and also to change internal energy.

B. No work is done in the process.

C. It is a constant volume process.

D. Temperature of the system changes during the process.

Answer: A

Solution:

In isochoric process, volume remains constant and hence no work is done. Hence statement (A) is incorrect.

Question300

If 'E' is the kinetic energy per mole of an ideal gas and 'T' is the absolute temperature, then the universal gas constant is given as

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Options:

A. $\frac{2\ T}{3E}$

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

C. $\frac{3\ T}{2E}$

D. $\frac{3E}{2\ T}$

Answer: B

Solution:

The kinetic energy per mole $E = \frac{3}{2}RT$

$\therefore R = \frac{2E}{3T}$

Question301

Two rods of same length and material are joined end to end. They transfer heat in 8 second. When they are joined in parallel they transfer same amount of heat in same conditions in time

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Options:

A. 3 s

B. 2 s

C. 1 s

D. 4 s

Answer: B

Solution:

Let R be the thermal resistance of each rod when connected in series, the total resistance will be

$\mathrm{R_s} = 2\mathrm{R}$

Whey they are connected in parallel, the effective resistance will be

$\mathrm{R_p} = \frac{\mathrm{R}}{2}$

$\therefore \frac{\mathrm{R_p}}{\mathrm{R_s}} = \frac{1}{4}$

In parallel combination, the resistance becomes one-fourth and hence time will also become one-fourth. $\therefore$ Time taken $\frac{8}{4} = 2$ s

----

Question302

The molar specific heats of an ideal gas at constant pressure and volume are denoted by '$\mathrm{C_p}$' and 'C_v' respectively. If $\gamma = \frac{C_p}{C_v}$ and 'R' is universal gas constant, then C_v is equal to

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Options:

A. $\frac{R}{\gamma-1}$

B. γR

C. $\frac{1+\gamma}{1-\gamma}$

D. $\frac{\gamma-1}{R}$

Answer: A

Solution:

$$\begin{aligned} & \gamma=\frac{C_p}{C_v}, \text{ Also } C_p-C_v=R \\ & C_p=\gamma C_v \\ \therefore & \gamma C_v-C_v=R \\ \therefore & C_v(\gamma-1)=R \\ \therefore & C_v=\frac{R}{\gamma-1} \end{aligned}$$

Question303

The temperature difference bewtween two sides of metal plate, $3 \mathrm{~cm}$ thick is $15^{\circ} \mathrm{C}$. Heat is transmitted through plate at the rate of $900 \mathrm{~kcal}$ per minute per m^2 at steady state. The thermal conductivity of metal is

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Options:

A. $1.8 \times 10^{-2} \frac{\mathrm{kcal}}{\mathrm{ms}^{\circ} \mathrm{C}}$

B. $4.5 \times 10^{-2} \frac{\mathrm{kcal}}{\mathrm{ms}^{\circ} \mathrm{C}}$

C. $3 \times 10^{-2} \frac{\mathrm{kcal}}{\mathrm{ms}^{\circ} \mathrm{C}}$

D. $6 \times 10^{-2} \frac{\text{kcal}}{\text{ms}^{\circ}\text{C}}$

Answer: C

Solution:

$$\frac{Q}{tA} = \frac{k\Delta\theta}{d}$$
$$\therefore k = \frac{Q}{tA} \cdot \frac{d}{\Delta\theta}$$
$$\frac{Q}{tA} = 900 \text{ kcal per minute per m}^2 = \frac{900}{60} = 15 \text{ kcal/sm}^2$$
$$d = 3 \text{ cm} = 3 \times 10^{-2} \text{ m}, \Delta\theta = 15^{\circ}\text{C}$$
$$\therefore k = \frac{15 \times 3 \times 10^{-2}}{15} = 3 \times 10^{-2} \text{kcal/ms}^{\circ}\text{C}$$

Question304

A black body has maximum wavelength 'λ_m' at temperature 2000 K. Its corresponding wavelength at temperature 3000 K will be

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Options:

A. $\frac{4\lambda_m}{9}$

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

C. $\frac{3\lambda_m}{2}$

D. $\frac{9}{4}\lambda_m$

Answer: B

Solution:

By Wien's displacement law $\lambda T = \text{constant}$

$$\therefore \lambda \propto \frac{1}{\mathrm{T}}$$

$$\therefore \frac{\lambda_2}{\lambda_1}=\frac{\mathrm{T}_1}{\mathrm{T}_1}=\frac{2000}{3000}=\frac{2}{3}$$

$$\therefore \lambda_2=\frac{2}{3} \lambda_1$$

Question305

A monoatomic gas at pressure 'P' having volume 'V' expands isothermally to a volume 2 V and then adiabatically to a volume 16 V. The final pressure of the gas is $\left(\gamma=\frac{5}{3}\right)$

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Options:

A. $\frac{P}{64}$

B. $\frac{\mathrm{P}}{128}$

C. $\frac{P}{8}$

D. $\frac{\mathrm{P}}{32}$

Answer: A

Solution:

For isothermal process: $\mathrm{P}_1 \mathrm{~V}_1=\mathrm{P}_2 \mathrm{~V}_2$

$\therefore \quad \mathrm{P}_2=\frac{\mathrm{P}_1 \mathrm{~V}_1}{\mathrm{~V}_2}=\frac{\mathrm{P}_1}{2} \quad\left(\because \frac{\mathrm{v}_1}{\mathrm{v}_2}=\frac{1}{2}\right)$

For adiabatic process : $\quad \mathrm{P}_2 \mathrm{~V}_2^\gamma=\mathrm{P}_3 \mathrm{~V}_3^\gamma$

$$\therefore \quad P_3=P_2\left(\frac{V_2}{V_3}\right)^\gamma=P_2\left(\frac{2 V_1}{V_3}\right)^\gamma=\frac{P_1}{2}\left(\frac{1}{8}\right)^{5 / 3} \quad\left[\because \frac{V_1}{V_3}=\frac{1}{16}\right]$$

$$=\frac{P_1}{2} \cdot \frac{1}{32}=\frac{P_1}{64}$$

Question306

A black reactangular surface of area 'a' emits energy 'E' per second at 27°C. If length and breadth is reduced to $\left(\frac{1}{3}\right)^{\text{rd}}$ of initial value and temperature is raised to 327°C then energy emitted per second becomes

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Options:

A. $\frac{16E}{9}$

B. $\frac{8E}{9}$

C. $\frac{4E}{9}$

D. $\frac{12E}{9}$

Answer: A

Solution:

$\mathrm{E} = \mathrm{e}\sigma \cdot \mathrm{A}\left(\mathrm{T}^4 - \mathrm{T}_0^4\right)$ and $\mathrm{A} = \ell \mathrm{b}$

When ℓ and b change to $\frac{\ell}{3}$ and $\frac{b}{3}$

$$A' = \frac{A}{9}$$
$$\frac{E'}{E} = \frac{A'}{A}\frac{(327+273)^4}{(27+273)^4}; \quad \frac{E'}{E} = \frac{1}{9}\left(\frac{600}{300}\right)^4$$
$$\therefore E' = \frac{1}{9} \times (2)^4 \times E \quad \Rightarrow E' = \frac{16E}{9}$$

Question307

Find the value of -197°C temperature in Kelvin.

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Options:

A. 47 K

B. 76 K

C. 470 K

D. 760 K

Answer: B

Solution:

Temperature in Kelvin $= -197 + 273 = 76$ K

Question308

Which one of the following equations specifies an isobaric process? $[Q =$ heat supplied $\Delta P, \Delta V$ and ΔT are change in pressure, volume and temperature respectively]

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Options:

A. $Q = 0$

B. $\Delta \mathrm{T} = 0$

C. $\Delta \mathrm{V} = 0$

D. $\Delta \mathrm{P} = 0$

Answer: D

Solution:

In isobaric process pressure remains constant.

Question309

A perfect gas of volume 10 litre n compressed isothermally to a volume of 1 litre. The rms speed of the molecules will

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Options:

A. decrease 5 times

B. remain unchanged

C. increase 5 times

D. increase 10 times

Answer: B

Solution:

Since it is compressed isothermally, the temperature remains constant. The rms speed is given by,

$c=\sqrt{\frac{3RT}{M}}$

Since temperature T remains constant, the rms speed remains unchanged.

Question310

The relation obeyed by a perfect gas during an adiabatic process is $\mathrm{PV}^{3/2}$. The initial temperature of the gas is 'T'. When the gas is compressed to half of its Initial volume, the final temperature of the gas is

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Options:

A. $2\sqrt{2}$ T

B. 4 T

C. $\sqrt{2}$ T

D. 2 T

Answer: C

Solution:

Relation between P and V is given as

$PV^{3/2} = $ constant

For adiabatic process, $PV^{\gamma} = $ constant

$\therefore \gamma = \frac{3}{2}$

The relation between T and V is given by

$$\begin{aligned} & TV^{\gamma-1} = \text{ constant} \\ \therefore & T_1 V_1^{\gamma-1} = T_0 V_0^{\gamma-1} \\ \therefore & T_1 V_1^{1/2} = T_0 V_0^{1/2} \\ \therefore & \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{1/2} = 2^{1/2} = \sqrt{2} \\ \therefore & T_2 = \sqrt{2}\, T_1 = \sqrt{2}\, T \end{aligned}$$

Question311

A black rectangular surface of area 'A' emits energy 'E' per second at 27°C. If length and breadth is reduced to $(1/3)^{\text{rd}}$ of its initial value and temperature is raised to 327°C then energy emitted per second becomes

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Options:

A. $\frac{20E}{9}$

B. $\frac{8E}{9}$

C. $\frac{16E}{9}$

D. $\frac{4E}{9}$

Answer: C

Solution:

The energy emitted by a black body per unit area per unit time (or power per unit area) is given by Stefan-Boltzmann Law :

σT^4

Where :

- σ is the Stefan-Boltzmann constant.
- T is the absolute temperature of the body.

Given :

Initial energy emitted E for area A at temperature $27°C = 273 + 27 = 300\text{K}$

$E = A\sigma(300^4)$

Now, the area is reduced to $(1/3)^2$ of its original value :

$A' = \left(\frac{1}{3}\right)^2 A = \frac{A}{9}$

The temperature is raised to $327°C = 273 + 327 = 600\text{K}$

The new energy emitted E' will be :

$E' = A'\sigma(600^4)$

Dividing the two equations :

$\frac{E'}{E} = \frac{A'\sigma(600^4)}{A\sigma(300^4)}$

Given $A' = \frac{A}{9}$ and using $(600^4)/(300^4) = 2^4 = 16$:

$\frac{E'}{E} = \frac{16}{9}$

So, $E' = \frac{16E}{9}$

The correct answer is :

Option C

$\frac{16E}{9}$

Question312

A monoatomic gas is suddenly compressed to $(1/8)^{th}$ of its initial volume adiabatically. The ratio of the final pressure to initial pressure of the gas is ($\gamma = 5/3$)

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Options:

A. 32

B. 8

C. $\frac{40}{3}$

D. $\frac{24}{5}$

Answer: A

Solution:

$\frac{V_2}{V_1} = \frac{1}{8}, \gamma = \frac{5}{3}$

For adiabatic process,

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$
$$\therefore \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma = (8)^{5/3} = (2)^5 = 32$$

Question313

A conducting rod of length $1 \mathrm{~m}$ has area of cross-section $10^{-3} \mathrm{~m}^2$. One end is immersed in baiting water $(100^{\circ}\mathrm{C})$ and the other end in Ice $(0^{\circ}\mathrm{C})$. If coefficient of thermal conductivity of rod is

$96 \mathrm{~cal/sm^{\circ}C}$ and latent heat for ice is $8 \times 10^{-4} \mathrm{cal/kg}$ then the amount of ice which will melt in one minute is

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Options:

A. $5.4 \times 10^{-3} \mathrm{~kg}$

B. $7.2 \times 10^{-3} \mathrm{~kg}$

C. $1.8 \times 10^{-3} \mathrm{~kg}$

D. $3.6 \times 0^{-3} \mathrm{~kg}$

Answer: B

Solution:

$$\begin{aligned} & \mathrm{d}=1 \mathrm{~m}, \ \mathrm{A}=10^{-3} \mathrm{~m}^2, \ \mathrm{K}=96 \mathrm{cal/sm^{\circ}C}, \mathrm{L}=8 \times 10^4 \mathrm{cal/kg} \\ & \mathrm{t}=1 \mathrm{~min}=60 \mathrm{~s}, \theta_1=0^{\circ}\mathrm{C}, \theta_2=100^{\circ}\mathrm{C} \\ & \mathrm{Q}=\frac{\mathrm{KA} \Delta \theta \mathrm{t}}{\mathrm{d}}=\mathrm{mL} \\ & \therefore \mathrm{m}=\frac{\mathrm{KA} \Delta \theta \mathrm{t}}{\mathrm{L}}=\frac{96 \times 10^{-3} \times 100 \times 60}{80 \times 10^4} \\ & \quad=7.2 \times 10^{-3} \mathrm{~kg} \end{aligned}$$

Question314

Two stars 'P' and 'Q' emit yellow and blue light respectively. The relation between their temperatures $\left(\mathrm{T_P}\right.$ and $\left.\mathrm{T_Q}\right)$ is

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Options:

A. $\mathrm{T_P}=\mathrm{T_Q}$

B. $T_P = \frac{T_Q}{2}$

C. $T_P > T_Q$

D. $T_P < T_Q$

Answer: D

Solution:

According to Wien's law, λT = constant

$\therefore T \propto \frac{1}{\lambda}$

Wavelength of blue light is less than that of yellow light. Hence, temperature of Q is greater than temperature of P.

Question315

A perfectly black body emits a radiation at temperature 'T_1' K. If it is to radiate at 16 times this power, its temperature 'T_2' K should be

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Options:

A. $8T_1$

B. $4T_1$

C. $2T_1$

D. $16T_1$

Answer: C

Solution:

$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4$

$\therefore 16 = \left(\frac{T_2}{T_1}\right)^4$

$\therefore \frac{T_2}{T_1} = 2$

Question316

One mole of an ideal gas expands adiabatically at constant pressure such that its temperature $T \propto \frac{1}{\sqrt{V}}$. The value of γ for the gas is ($\gamma = \frac{C_p}{C_v}, V =$ Volume of the gas)

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Options:

A. 1.8

B. 1.5

C. 1.3

D. 1.4

Answer: B

Solution:

For adiabatic process at constant pressure we have

$\mathrm{TV}^{\gamma-1}$ = constant ...... (1)

Given $T \propto \frac{1}{\sqrt{V}}$

$\therefore \mathrm{TV}^{1/2}$ = constant

By (1) and (2) $\gamma - 1 = \frac{1}{2}$

$\gamma = 1.5$

Question317

On an imaginary linear scale of temperature (called 'W' scale) the freezing and boiling points of water are 39° W and 239° W respectively. The temperature on the new scale corresponding to 39° C temperature on Celsius scale will be

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Options:

A. 139° W

B. 78° W

C. 117° W

D. 200° W

Answer: C

Solution:

In Celsius scale the freezing and boiling points are 0°C and 100°C. In the given imaginary scale the freezing and boiling points are 39° W and 239° W. Hnece we can write

$\frac{C}{100} = \frac{W-39}{200}$

For C = 39°, $\frac{39}{100} = \frac{W-39}{200}$

Solving, W = 117°C

Question318

Specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v respectively. If $\gamma = \frac{C_p}{C_v}$ and R it's the universal gas constant then C_v is equal to

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Options:

A. $\frac{(\gamma-1)}{(\gamma+1)}$

B. $\frac{(\gamma-1)}{\mathrm{R}}$

C. $\mathrm{R}\gamma$

D. $\frac{R}{(\gamma-1)}$

Answer: D

Solution:

$$\gamma=\frac{C_p}{C_v}, \text{ Also } C_p-C_v=R$$
$$C_p=\gamma C_v$$
$$\therefore \gamma C_v-C_v=R \quad \therefore C_v(\gamma-1)=R \quad \therefore C_v=\frac{R}{\gamma-1}$$

Question319

For a monoatomic gas, work done at constant pressure is W. The heat supplied at constant volume for the same rise in temperature of the gas is

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Options:

A. W

B. $\frac{5\mathrm{W}}{2}$

C. $\frac{\mathrm{W}}{2}$

D. $\frac{3\mathrm{W}}{2}$

Answer: D

Solution:

Heat supplied at constant pressure $Q_1 = nC_p dT$

Heat supplied at constant volume $Q_2 = nC_v dT$

Work done

$$W = Q_1 - Q_2 = n(C_p - C_v)dT$$
$$\therefore \frac{W}{Q_2} = \frac{C_p - C_v}{C_v} = \frac{C_p}{C_v} - 1 = \frac{5}{3} - 1 = \frac{2}{3}$$
$$\therefore Q_2 = \frac{3W}{2}$$

Question320

The root mean square velocity of molecules of a gas is $200 \mathrm{~m/s}$. What will be the root mean square velocity of the molecules, if the molecular weight is doubled and the absolute temperature is halved?

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Options:

A. $50 \mathrm{~m/s}$

B. $200 \mathrm{~m/s}$

C. $100 \mathrm{~m/s}$

D. $\frac{100}{\sqrt{2}} \mathrm{~m/s}$

Answer: C

Solution:

The root mean square (rms) velocity of gas molecules is given by the formula:

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

This shows that:

$$v_{\text{rms}} \propto \sqrt{\frac{T}{M}}$$

If we have two scenarios with different conditions and we are comparing their rms velocities, the relationship can be expressed as:

$$\frac{(v_{\text{rms}})_1}{(v_{\text{rms}})_2} = \sqrt{\frac{T_1}{M_1}} \times \sqrt{\frac{M_2}{T_2}}$$

Here, when the molecular weight is doubled, $M_2 = 2M_1$, and when the absolute temperature is halved, $T_2 = \frac{T_1}{2}$.

Substituting these values into the equation, we get:

$$\frac{(v_{\text{rms}})_1}{(v_{\text{rms}})_2} = \sqrt{\frac{T_1}{M_1}} \times \sqrt{\frac{4M_1}{T_1}} = 2$$

This implies that:

$$(v_{\text{rms}})_2 = \frac{(v_{\text{rms}})_1}{2} = \frac{200}{2} = 100\,\text{m/s}$$

Question321

Two spherical black bodies of radius r_1 and r_2 with surface temperature T_1 and T_2 respectively, radiate same power, then $r_1 : r_2$ is

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Options:

A. $\left(\frac{T_2}{T_1}\right)^4$

B. $\left(\frac{T_2}{T_1}\right)^2$

C. $\left(\frac{T_1}{T_2}\right)^2$

D. $\left(\frac{T_1}{T_2}\right)^4$

Answer: B

Solution:

The power radiated by a black body can be described by the formula:

$E = \varepsilon\sigma AT^4$

Where:

ε is the emissivity of the body,

σ is the Stefan-Boltzmann constant,

A is the surface area,

T is the surface temperature.

For a spherical black body, the area A is given by $4\pi r^2$.

Given that two spherical bodies radiate the same power, we have:

$E_1 = E_2$

So:

$\varepsilon\sigma(4\pi r_1^2)T_1^4 = \varepsilon\sigma(4\pi r_2^2)T_2^4$

Since emissivity, the Stefan-Boltzmann constant, and 4π are common, they cancel out:

$T_1^4 r_1^2 = T_2^4 r_2^2$

Rearranging gives:

$\frac{r_1}{r_2} = \left(\frac{T_2}{T_1}\right)^2$

Question322

A diatomic gas undergoes adiabatic change. Its pressure p and temperature T are related as $p \propto T^x$, where x is

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Options:

A. 3.0

B. 1.5

C. 2.5

D. 3.5

Answer: D

Solution:

For a diatomic gas undergoing an adiabatic change, the relationship between pressure (p) and temperature (T) is defined by:

$\frac{T^\gamma}{p^{\gamma-1}} = \text{constant}$

This equation can be rearranged to:

$T^\gamma = \text{constant} \times p^{\gamma-1}$

By simplifying further, we find:

$p \propto T^{\frac{\gamma}{\gamma-1}}$

Given that $p \propto T^x$, we equate the exponents:

$x = \frac{\gamma}{\gamma-1}$

For a diatomic gas, the adiabatic index γ is $\frac{7}{5}$. Substituting this value, we calculate:

$x = \frac{\frac{7}{5}}{\frac{7}{5}-1}$

This simplifies to:

$x = \frac{\frac{7}{5}}{\frac{2}{5}} = \frac{7}{2} = 3.5$

Therefore, for a diatomic gas undergoing an adiabatic process, the value of x is 3.5.

Question323

For a gas, $\frac{R}{C_V} = 0.4$, where R is universal gas constant and C_V is the molar specific heat at constant volume. The gas is made up of molecules, which are

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Options:

A. polyatomic

B. rigid diatomic

C. monoatomic

D. non-rigid diatomic

Answer: B

Solution:

As, we know, $C_p = C_v + R$

$$\Rightarrow \quad \frac{C_p}{C_V} = 1 + \frac{R}{C_v}$$

Here, $\frac{R}{C_v} = 0.4$ and also, $\frac{C_p}{C_v} = 1 + \frac{2}{f}$

$$\Rightarrow \quad 1 + \frac{2}{f} = 1 + 0.4$$

$$\text{or} \quad \frac{2}{f} = 0.4$$

$$\text{or} \quad f = \frac{2}{0.4} = 5$$

As, degree of freedom is 5, so the gas is made up of molecules which are rigid diatomic (no vibrations).

Question324

A monoatomic gas of pressure p having volume V expands isothermally to a volume $2V$ and then adiabatically to a volume 16 V . The final pressure of the gas is (ratio of specific heats $= \frac{5}{3}$

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Options:

A. $\frac{p}{8}$

B. $\frac{p}{16}$

C. $\frac{p}{64}$

D. $\frac{p}{32}$

Answer: C

Solution:

In isothermal expansion,

$$p_1 V_1 = p_2 V_2$$
$$\Rightarrow \quad pV = p_2(2V) \Rightarrow p_2 = \frac{p}{2}$$

In adiabatic expansion,

$$p_2 V_2^\gamma = p_3 V_3^\gamma$$

For monoatomic gas, $\gamma = \frac{5}{3}$

$$\Rightarrow \quad \frac{p}{2}(2V)^{\frac{5}{3}} = p_3(16V)^{\frac{5}{3}}$$
$$\Rightarrow \quad p_3 = \frac{p}{2} \times \frac{1}{8^{\frac{5}{3}}} = \frac{p}{2 \times 2^5} = \frac{p}{64}$$

Question325

The SI unit and dimensions of Stefan's constant σ in case of Stefan's law of radiation is

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Options:

A. $\frac{\mathrm{J}}{\mathrm{m}^3\ \mathrm{s}^4}, \left[M^1 L^0 T^{-3} K^{-4}\right]$

B. $\frac{\mathrm{J}}{\mathrm{m}^2\ \mathrm{s}^4\ \mathrm{K}}, \left[M^1 L^0 T^{-3} K^3\right]$

C. $\frac{\mathrm{J}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}^4}, \left[\mathrm{M}^1 \mathrm{L}^0\ \mathrm{T}^{-3}\ \mathrm{K}^4\right]$

D. $\frac{\mathrm{J}}{\mathrm{m}^2\ \mathrm{s}\ \mathrm{K}^4}, \left[\mathrm{M}^1\ \mathrm{L}^0\ \mathrm{T}^{-3}\ \mathrm{K}^{-4}\right]$

Answer: D

Solution:

According to Stefan's law, energy emitted by a body per unit area per second is proportional to fourth power of the absolute temperature.

$$E = \sigma T^4$$

where, $E =$ energy emitted/area/second, $T =$ absolute temperature in kelvin and $\sigma =$ Stefan's constant.
$\Rightarrow \sigma = \frac{E}{T^4}$

Unit of Stefan's constant

Unit of Stefan's

$$\Rightarrow \quad \frac{\mathrm{J/m^2\ s}}{\mathrm{K^4}} = \mathrm{J/m^2\ s\ K^4}$$

nimonsions of Stefan's constant,

Dimensions of Stefan's constant,

$$\sigma = \frac{[\text{ Energy }]}{[\text{ Area }] \times [\text{ Time }] \times [\text{ Temperature }]^4}$$

$$= \frac{\left[\mathrm{ML^2\ T^{-2}}\right]}{[\mathrm{L^2\ T \times K^4}]} = \left[\mathrm{M^1\ L^0\ T^{-3}\ K^{-4}}\right]$$

Question326

The rms speed of oxygen molecule in a gas is u, If the temperature is doubled and the molecules dissociates into two atoms, the rms speed will be

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Options:

A. 4u

B. u

C. 2u

D. $u\sqrt{2}$

Answer: C

Solution:

To determine the new root mean square (rms) speed of the oxygen molecules when the temperature is doubled and they dissociate into atoms, we can use the formula for the rms speed:

$$v_{\text{rms}} = \sqrt{\frac{3kT}{m}}$$

where:

v_{rms} is the root mean square speed,

k is the Boltzmann constant,

T is the temperature,

m is the mass of a molecule.

Initially, the oxygen molecule (O_2) has a mass m, and its rms speed is u. Therefore:

$u=\sqrt{\frac{3kT}{M}}$

where M is the molar mass of the oxygen molecule O_2.

When the temperature is doubled $(T'=2T)$, and oxygen molecules dissociate into atoms, the mass of an individual oxygen atom is $\frac{M}{2}$. The new rms speed u' can be calculated as:

$u'=\sqrt{\frac{3k(2T)}{\frac{M}{2}}}$

This simplifies to:

$u'=\sqrt{\frac{6kT}{\frac{M}{2}}}=\sqrt{\frac{6kT\cdot 2}{M}}=\sqrt{\frac{12kT}{M}}=\sqrt{4\cdot\frac{3kT}{M}}$

The term $\frac{3kT}{M}$ corresponds to the square of the initial rms speed, u^2:

$u'=\sqrt{4}\cdot u=2u$

Thus, the new rms speed will be $2u$. Therefore, the correct answer is:

Option C: 2u.

Question327

The equation of state for 2 g of oxygen at a pressure ' P ' and temperature ' T, when occupying a volume ' V ' will be

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Options:

A. $pV=16RT$

B. $pV=RT$

C. $pV = \frac{1}{16} RT$

D. $pV = 2RT$

Answer: C

Solution:

The equation of state for a gas can be described using the ideal gas law:

$pV = \mu RT$

where:

p is the pressure,

V is the volume,

μ is the number of moles of the gas,

R is the ideal gas constant, and

T is the temperature.

The number of moles (μ) is calculated using the formula:

$\mu = \frac{\text{Given mass}}{\text{Molecular mass}} = \frac{m}{M}$

For this specific problem:

The given mass of oxygen (m) is 2 g.

The molecular mass (M) of oxygen (O_2) is 32 g/mol.

Substituting these values into the formula, we have:

$\mu = \frac{2 \text{ g}}{32 \text{ g/mol}} = \frac{1}{16} \text{ mol}$

Now, substituting μ back into the ideal gas equation:

$pV = \frac{1}{16} RT$

Therefore, the equation of state for 2 g of oxygen under the given conditions is:

$pV = \frac{1}{16} RT$

Question328

The maximum wavelength of radiation emitted by a star is 289.8 nm . Then intensity of radiation for the star is (Given : Stefan's constant $= 5.67 \times 10^{-8} \mathrm{Wm}^{-2} \mathrm{~K}^{-4}$, Wien's constant, $b = 2898 \mu \mathrm{mK}$)

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Options:

A. $5.67 \times 10^{-12} \mathrm{Wm}^{-2}$

B. $10.67 \times 10^{14} \mathrm{Wm}^{-2}$

C. $5.67 \times 10^{8} \mathrm{Wm}^{-2}$

D. $10.67 \times 10^{7} \mathrm{Wm}^{-2}$

Answer: C

Solution:

Given, maximum wavelength,

$$\begin{aligned} \lambda_m &= 289.8 \text{ nm} = 289.8 \times 10^{-9} \text{ m} \\ &= 2898 \times 10^{-10} \text{ m} \end{aligned}$$

Stefan's constant, $\sigma = 5.67 \times 10^{-8} \mathrm{Wm}^{-2} \mathrm{~K}^{-4}$

Wien's constant, $b = 2898 \mu\mathrm{mK} = 2898 \times 10^{-6} \mathrm{mK}$

According to Wien's displacement law, the maximum wavelength is given by

$\lambda_m = \frac{b}{T} \Rightarrow T = \frac{b}{\lambda_m}$ .... (i)

Substituting given values in Eq. (i), we get

$T = \frac{2898 \times 10^{-6}}{2898 \times 10^{-10}} = 10^4 \mathrm{~K}$ .... (ii)

According to Stefan's law, the energy radiated from a source is given by

$E = \sigma A e T^4$ .... (iii)

where, $A =$ area of source

$e =$ emissivity (value between 0 to 1)

The intensity of radiations emitted is equal to energy radiated from a given surface area, i.e.,

$I = \frac{E}{A} = \sigma e T^4$ [from Eq. (iii)]

As e is very small, so

$I = \sigma T^4$ .... (iv)

Substituting the value of T from Eq. (ii) in Eq. (iv), we get

$$I = \sigma\left(10^4\right)^4 = 5.67 \times 10^{-8} \times 10^{16}$$
$$\left[\because \sigma = 5.67 \times 10^{-8} \text{ (given)}\right]$$
$$= 5.67 \times 10^8 \mathrm{Wm}^{-2}$$

Question329

If ' C_P ' and ' C_V ' are molar specific heats of an ideal gas at constant pressure and volume respectively. If ' λ ' is the ratio of two specific heats and ' R ' is universal gas constant then ' C_p ' is equal to

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Options:

A. $\frac{R\gamma}{\gamma-1}$

B. γR

C. $\frac{1+\gamma}{1-\gamma}$

D. $\frac{R}{\gamma-1}$

Answer: A

Solution:

Given that the ratio of the molar specific heats at constant pressure (C_p) and constant volume (C_v) is γ, we need to find the expression for C_p. The universal gas constant is denoted by R.

The relationship between C_p and C_v for an ideal gas is given by Mayer's relation:

$C_p - C_v = R$

By substituting C_p from the above relation into the expression for γ, we have:

$\gamma = \frac{C_p}{C_v} = \frac{C_p}{C_p - R}$

To solve for C_p, multiply both sides by $(C_p - R)$:

$\gamma(C_p - R) = C_p$

Expanding and rearranging terms, we get:

$\gamma C_p - C_p = \gamma R$

Factor out C_p on the left side:

$C_p(\gamma - 1) = \gamma R$

Finally, solve for C_p:

$C_p = \frac{\gamma R}{\gamma - 1}$

Thus, C_p is equal to $\frac{\gamma R}{\gamma - 1}$.

Question330

A clock pendulum having coefficient of linear expansion. $\alpha = 9 \times 10^{-7} / {}^\circ\mathrm{C}^{-1}$ has a period of 0.5 s at $20^\circ\mathrm{C}$. If the clock is used in a climate, where the temperature is $30^\circ\mathrm{C}$, how much time does the clock lose in each oscillation? ($g =$ constant)

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Options:

A. 25×10^{-7} s

B. 5×10^{-7} s

C. 1.125×10^{-6} s

D. 2.25×10^{-6} s

Answer: D

Solution:

Given the problem, we start with the following information:

Coefficient of linear expansion, $\alpha = 9 \times 10^{-7}\,{}^\circ\mathrm{C}^{-1}$.

Initial period of the pendulum, $T_0 = 0.5\,\mathrm{s}$.

Initial temperature, $T_i = 20^\circ\mathrm{C}$.

Final temperature, $T_f = 30°\text{C}$.

Calculation Steps:

Determine the expansion in length due to temperature change:

$$\Delta l = l \times \alpha \times (T_f - T_i)$$

Substituting the values:

$$\Delta l = l \times 9 \times 10^{-7} \times (30 - 20)$$

Formulate the time period of the pendulum:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Find the error in the time period:

$$\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} + \frac{1}{2}\frac{\Delta g}{g}$$

Note: Since $\Delta g = 0$, this simplifies to:

$$\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l}$$

Substitute the changes into the equation:

$$\frac{\Delta T}{0.5} = \frac{1}{2}\left(\frac{9 \times 10^{-7} \times 10}{1}\right)$$

Calculate ΔT:

$$\Delta T = \frac{0.5 \times 9 \times 10^{-7} \times 10}{2}$$

$$\Delta T = 2.25 \times 10^{-6}\ \text{s}$$

Thus, the clock loses 2.25×10^{-6} seconds in each oscillation when the temperature increases to $30°\text{C}$.

Question331

If α is the coefficient of performance of a refrigerator and ' Q ' is heat released to the hot reservoir, then the heat extracted from the cold reservoir ' Q_2 ' is

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Options:

A. $\frac{\alpha Q_1}{\alpha-1}$

B. $\frac{\alpha-1}{\alpha} Q_1$

C. $\frac{\alpha Q_1}{1+\alpha}$

D. $\frac{1+\alpha}{\alpha} Q_1$

Answer: C

Solution:

To determine the heat extracted from the cold reservoir, Q_2, in a refrigerator, we use the relationship involving the coefficient of performance α. The coefficient of performance of a refrigerator is defined as:

$\alpha = \frac{Q_2}{W}$

where W is the work done by the refrigerator, given by:

$W = Q_1 - Q_2$

Substituting into the formula for α:

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

Rearranging the equation to express Q_2 in terms of Q_1 and α:

$\alpha(Q_1 - Q_2) = Q_2$

Simplifying further:

$\alpha Q_1 - \alpha Q_2 = Q_2$

Adding αQ_2 to both sides and factoring out Q_2 gives:

$\alpha Q_1 = Q_2 + \alpha Q_2$

$\alpha Q_1 = Q_2(1 + \alpha)$

Finally, solving for Q_2:

$Q_2 = \frac{\alpha Q_1}{1+\alpha}$

This formula shows the relationship between the coefficient of performance and the heat exchanged in the refrigerator system.
