PHYSICS

Q.1 The pressure and volume of a given mass of gas at a given temperature are P and V respectively. Keeping temperature constant, the pressure is increased by 10% and then decreased by 10%. The volume how will be -

(A) less than V

(B) more than V

(C) equal to V

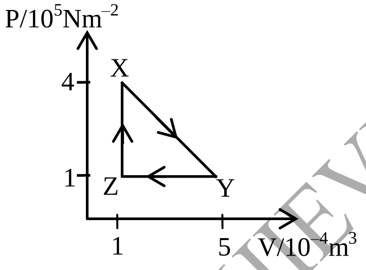
(D) less than V for diatomic and more than V for monoatomic **[B]**

Sol. When the pressure is first increased by 10% it becomes (110/100) P. when it is decreased by 10% from there, the pressure becomes

$$\frac{110 \times 90}{100 \times 100} \text{ P} = \frac{99}{100} \text{ P}$$

Thus the pressure decreases by 1% volume is increased by nearly 1%

Q.2 A mass of an ideal gas of volume V at pressure P undergoes the cycle of changes shown in the graph –



At which point is the gas coolest and hottest ?

Coolest	hottest
(A) X	Y
(B) Y	X
(C) Y	Z
(D) Z	Y

[C]

Sol. For a mole of an ideal gas, the equation of state is PV = RT

or $T = \frac{PV}{R}$

which is proportional to the product pV

At x , PV = $(4 \times 10^5)(1 \times 10^{-4})$ = 40 Nm

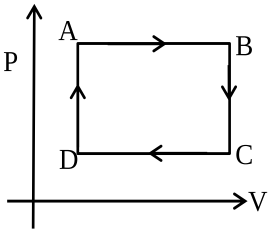
At y, pV = $(1 \times 10^5)(5 \times 10^{-4})$ = 50 Nm

At z, pV = $(1 \times 10^5)(1 \times 10^{-4})$ = 10 Nm

Thus, T is maximum at y since pV is the highest and T is minimum at z since pV is the smallest

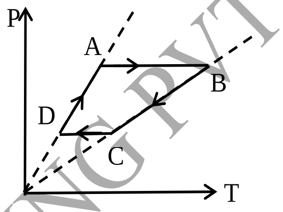
PV = RT

Q. 3 In the following cyclic process is

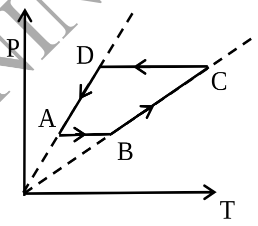


The above process in the P-T coordinates is given as

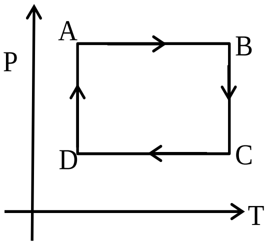
(A)



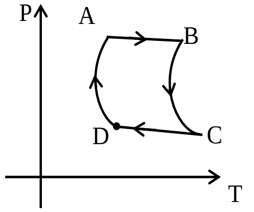
(B)



(C)

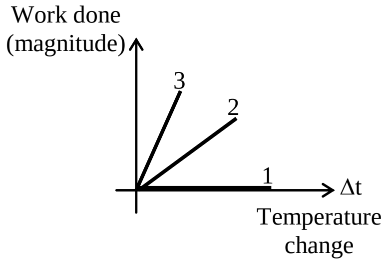


(D)



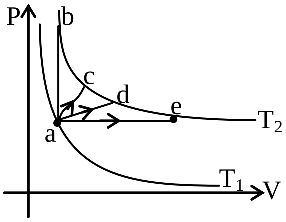
[A]

Q. 4 For an ideal gas graph is shown for three processes. Processes 1, 2 and 3 are respectively–



(A) Isochoric, isobaric, adiabatic
(B) Isochoric, adiabatic, isobaric
(C) Isobaric, adiabatic, isochoric
(D) Adiabatic, isobaric, isochoric **[B]**

Q. 5 The figure shows two isotherms at temperatures T_1 & T_2. A gas is taken from one isotherm to another isotherm through different processes. Then change in internal energy ΔU has relation–



(A) $\Delta U_{ab} > \Delta U_{ac} > \Delta U_{ad} > \Delta U_{ae}$
(B) $\Delta U_{ab} = \Delta U_{ac} > \Delta U_{ad} > \Delta U_{ae}$
(C) $\Delta U_{ab} = \Delta U_{ac} = \Delta U_{ad} = \Delta U_{ae}$
(D) $\Delta U_{ab} < \Delta U_{ac} < \Delta U_{ad} < \Delta U_{ae}$ **[C]**

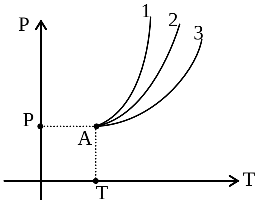
Q. 6 An ideal gas whose adiabatic exponent is γ is expanded so that the amount of heat transferred to the gas is equal to the decrease of its internal energy. Molar heat capacity of the gas for this process is –

(A) $\frac{R}{1-\gamma}$ (B) $\frac{R}{\gamma-1}$
(C) R (D) $\frac{R}{2}$ **[A]**

Q. 7 The molar heat capacity for a process is $C = \frac{R}{\gamma-1} + \frac{\alpha}{T}$, then process equation is –

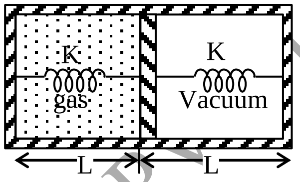
(A) $Ve^{-(\alpha/R)T}$ = Constant (B) $Ve^{(\alpha/R)T}$ = constant
(C) VT = constant (D) V/T = constant
[B]

Q. 8 The curves shown represent adiabatic curves for monoatomic, diatomic & polyatomic (γ = 4/3) gases. The slopes for curves 1, 2, 3 respectively at point A are –



(A) $2.5\frac{P}{T}, 3.5\frac{P}{T}, 4.5\frac{P}{T}$ (B) $2.5\frac{P}{T}, 3\frac{P}{T}, 4\frac{P}{T}$
(C) $2.5\frac{P}{T}, 3.5\frac{P}{T}, 4\frac{P}{T}$ (D) $2\frac{P}{T}, 3\frac{P}{T}, 4\frac{P}{T}$
[C]

Q. 9 When heat is supplied to the gas it expands and displaces piston by L/2 where natural length of springs are L = 1 m. Spring constant K = 100 N/m. Area of piston is 1 m^2. The pressure of gas in final situation is –



(A) 50 N/m^2 (B) 100 N/m^2
(C) 200 N/m^2 (D) 400 N/m^2 **[B]**

Q. 10 An ideal gas is expanded so that amount of heat given is equal to the decrease in internal energy. The gas undergoes the process $TV^{1/5}$ = constant. The adiabatic compressibility of gas when pressure is P, is –

(A) $\frac{7}{5P}$ (B) $\frac{5}{7P}$
(C) $\frac{2}{5P}$ (D) $\frac{7}{3P}$ **[B]**

Sol.

$dQ = -dU$

$$C = -C_V = \frac{-R}{\gamma-1} = \frac{+R}{\gamma-1} + \frac{P}{n}\frac{dV}{dT}$$

$$\boxed{-\frac{P}{n}\frac{dV}{dT} = \frac{2R}{\gamma-1}}$$

T^5V = const.

$$V = \frac{\text{const}}{T^5}$$

$$\frac{dV}{dT} = -5\frac{\text{const}}{T^6}$$

PV = nRT

P/n = RT/V

$$+\frac{RT}{\text{const}}T^5 \times \left(-5\frac{\text{const}}{T^6}\right) = \frac{2R}{\gamma-1}$$

$$\frac{5}{2} = \frac{1}{\gamma-1} \Rightarrow \gamma - 1 = 2/5$$

$\gamma = 7/5$

adiabatic compressibility

$$\beta = \frac{1}{\gamma P} = \frac{5}{7P}$$

Q. 11 A mixture of 8gm of helium and 14gm of nitrogen is enclosed in a vessel of constant volume at 300K. The quantity of heat absorbed by the mixture to double the root mean velocity of its molecules is –

(R = universal gas constant)

(A) 2725 R (B) 3630 R

(C) 3825 R (D) 5625 R

Sol. **[C]**

$Q = \Delta U + W$

W = 0 since volume is constant

$Q = \Delta U$

$V_{rms} = \sqrt{3RT/M}$

$U_{mix} = U_1 + U_2$

$U_{mix} = n_1 C_{v_1} T + n_2 C_{v_2} T = (n_1 + n_2)(C_v)_{mix} T$

$(U_f) - (U_i) = nC_v(T_2 - T_1) = (n_1 + n_2)(C_v)_{mix}(T_2 - T_1)$

$V'_{rms} = 2V_{rms} \Rightarrow T' = 4T$

$n_1 = \frac{8}{4} = 2 \; ; \; n_2 = \frac{14}{28} = 1/2$

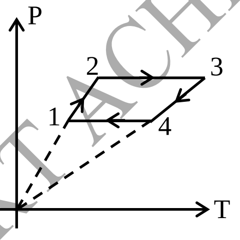
$(C_v)mix = \frac{n_1 Cv_1 + n_2 Cv_2}{(n_1 + n_2)}$

$U_f - U_i = (n_1 C_{v_1} + n_2 C_{v_2})(T_2 - T_1)$

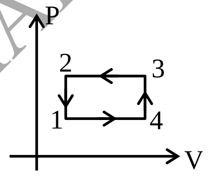
$= \left(2 \times \frac{3}{2} + \frac{1}{2} \times \frac{5}{2}\right) R\,[1200 - 300]$

$\frac{17}{4} \times R \times 100 = 3825\,R$

Q. 12 P-T graph of ideal monoatomic gas is given as shown in figure. The corresponding P-V diagram is



(A)



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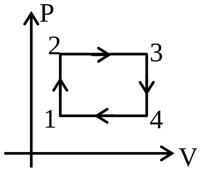
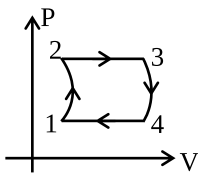
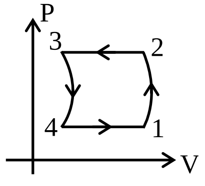


(C)



(D)



Sol. **[B]**

$1 \rightarrow 2$ = isochoric

$2 \rightarrow 3$ = isobaric

$3 \rightarrow 4$ = isochoric

$4 \rightarrow 1$ = isobaric

Q. 13 An expansion process on a diatomic ideal gas ($C_v = 5/2\ R$), has a linear path between the initial and final coordinates on a pV diagram. The coordinates of the initial state are : the pressure is 300 kPa, the volume is 0.08 m^3 and the temperature is 390 K. The final pressure is 90kPa and the final temperature is 320 K. The change in the internal energy of the gas, in SI units, is closest to:

(A) –11, 000 (B) –6500

(C) 11, 000 (D) zero

Sol. **[A]**

$\Delta U = nC_v \Delta T$

$= n\frac{5}{2}R(T_f - T_i)$

$n = \frac{P_1 V_1}{RT_1}$

$\Delta U = \frac{P_1 V_1}{RT_1} \times \frac{5}{2} R (T_2 - T_1)$

$= \frac{300 \times 10^3 \times 0.08}{390} \times \frac{5}{2}(320 - 390)$

$= \frac{15 \times 10^3 \times 0.08 \times 5}{39} \times (-70)$

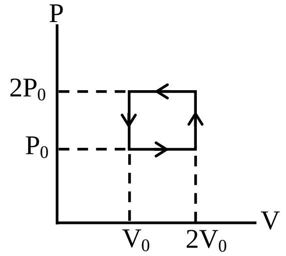
$= -\frac{0.40}{39} \times 15 \times 10^3 \times 70$

$= -\frac{40}{39} \times 150 \times 70$

$= -\frac{40}{39} \times 10500$

$\Delta U = -11000$ Joule

Q. 14 In Figure, an ideal gas is carried around the cyclic process. How much work is done in one cycle if $P_0 = 8$atm and $V_0 = 7.00$ liters.



(A) 5656 J (B) –5656 J

(C) 10,600 J (D) 11,300 J

Sol. **[B]**

Work done is area
under the curve

$W = -P_oV_o$

$= -8 \times (10^5 \times 1.01) \times 7 \times 10^{-3}$

$W = -56 \times 1.01 \times 10^2$ Joule

$W = -5656$ Joule

Q. 15 Which of the following is a FALSE statement?

(A) Heat is energy transferred into or out of a system as a result of a temperature difference between the system and its surroundings.

(B) The heat added to an ideal gas during the transition from state 1 to state 2 depends only on the initial and final states, 1 and 2, and not on the path by which the gas went from one to the other.

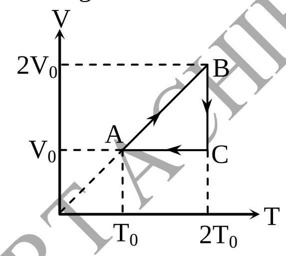
(C) When a gas goes from one state to another, the work done depends on the path followed

(D) It does not make sense to refer to "the amount of heat in a body".

Sol. **[B]**

Heat is a path function. Heat transfer depends on process. Hence heat transfer is different for different paths between same initial & final status.

Q.16 An ideal mono-atomic gas undergoes a cyclic process ABCA as shown in the figure. The ratio of heat absorbed during AB to the work done on the gas during BC is –



(A) $\frac{5}{2\ln 2}$ (B) $\frac{5}{3}$

(C) $\frac{5}{4\ln 2}$ (D) $\frac{5}{6}$

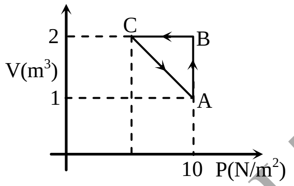
Sol. **[C]**

$Q_{AB} = nC_P\Delta T = n\frac{5}{2}R(2T_0 - T_0)$

$Q_{BC} = W_{BC} = NR.2T_0 \ln 2$

$\Rightarrow \frac{Q_{AB}}{W_{BC}} = \frac{5}{4\ln 2}$

Q.17 An ideal gas is taken through the cycle $A \rightarrow B \rightarrow C \rightarrow A$, as shown in the figure. If the net heat supplied to the gas in the cycle is 5 J, the work done by the gas in the process $C \rightarrow A$ is –



(A) –5 J (B) – 10 J

(C) – 15 J (D) – 20 J

Sol. **[A]**

$\Delta W_{AB} = P\Delta V = (10)(2 - 1) = 10$ J

$\Delta W_{BC} = 0$

From first law of thermodynamics

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

$\Delta U = 0$ (process ABCA is cyclic)

$\therefore \Delta Q = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$

$\therefore \Delta W_{CA} = \Delta Q - \Delta W_{AB} - \Delta W_{BC} = 5 - 10 - 0$

$= -5$ J

Q.18 The equation of process of a diatomic gas is $P^2 = \alpha^2 V$, where α is a constant. Then choose the correct option-

(A) Work done by gas for a temperature change T is $\frac{2}{3}\alpha$ nRT

(B) The change in internal energy is $\frac{5}{2}$ nRT for a temperature change T

(C) Specific heat for the process is $\frac{19}{9}$ R

(D) The change in internal energy for a temperature change T is $\frac{5}{2}$ αnRT

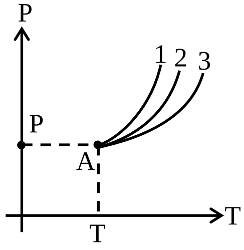
Sol. **[B]** Internal energy change is

$\Delta U = n\,C_V\,\Delta T$

$= n\frac{5}{2}R\,(T - 0)$

$= \frac{5}{2}$ nRT

Q.19 The curves shown represent adiabatic curves for monoatomic, diatomic & polyatomic ($\gamma = 4/3$) gases. The slopes for curves 1,2,3 respectively at point A are –



(A) $2.5\ \frac{P}{T}$, $3.\ 5\ \frac{P}{T}$, $4.5\ \frac{P}{T}$

(B) $2.5\ \frac{P}{T}$, $3\ \frac{P}{T}$, $4\ \frac{P}{T}$

(C) $2.5\ \frac{P}{T}$, $3.5\ \frac{P}{T}$, $4\ \frac{P}{T}$

(D) $4\ \frac{P}{T}$, $3.5\ \frac{P}{T}$, $2.5\ \frac{P}{T}$

Sol. **[D]**

For adiabatic process :

Slope : $\frac{dP}{dT} = \left(\frac{\gamma}{\gamma-1}\right)\frac{P}{T}$

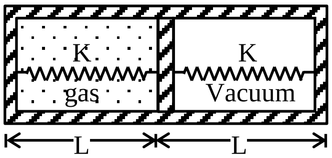
$$\gamma = \frac{5}{3}\Big|\ \frac{dP}{dT} = \left(\frac{5/3}{5/3-1}\right)\frac{P}{T} = \frac{5/3}{2/3}\ \frac{P}{T}$$

$= 2.5\ \frac{P}{T}$

$$\gamma = \frac{7}{5}\Big|\ \frac{dP}{dT} = \left(\frac{7/5}{2/5}\right)\frac{P}{T} = 3.5\ \frac{P}{T}$$

$$\gamma = \frac{4}{3}\Big|\ \frac{dP}{dT} = \left(\frac{4/3}{1/3}\right)\frac{P}{T} = 4\ \frac{P}{T}$$

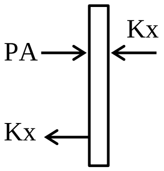
Q.20 Area of piston is 1 m^2. When heat is supplied to the gas it expands and displaces piston by $\frac{L}{2}$ where L = 1m. Natural length of springs is L = 1m. Spring constant K = 100 N/m. The pressure of gas in final situation is –



(A) 50 N/m^2 (B) 100 N/m^2

(C) 200 N/m^2 (D) 400 N/m^2

Sol. **[B]**



$P = \frac{2Kx}{A}$

$= \frac{2\times100}{1} \times \frac{1}{2}$

$= 100\ N/m^2$

Q.21 The internal energy of a diatomic gas is given as $U = U_0V$, where U_0 is a constant. Molar heat capacity of gas is –

(A) $\frac{5}{2}$ R

(B) $\frac{7}{2}$ R

(C) $\frac{9}{2}$ R

(D) $\frac{3}{2}$ R

Sol. **[B]**

$U = U_0V \Rightarrow nC_VT = U_0V \Rightarrow T \propto V$ isobaric process

$$\boxed{C = C_V + \frac{P}{n}\frac{dV}{dT}}$$

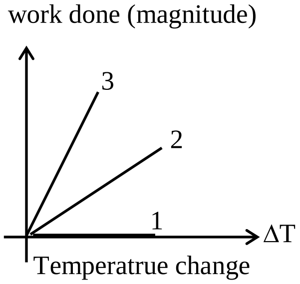
$\frac{dV}{dT}$ = constant

$\frac{P}{n} = \frac{nRT}{V} = \frac{nRT}{\text{constantT}}$

$C = C_V + \frac{R}{\text{constant}}$

$C = C_V + R = \frac{5}{2}\ R + R = \frac{7}{2}\ R$

Q.22 For an ideal gas graph is shown for three processes. Processes 1, 2, and 3 are respectively –



(A) Isochoric, isobaric, adiabatic
(B) Isochoric, adiabatic, isobaric
(C) isobaric, adiabatic, isochoric
(D) Adiabatic, isobaric, isochoric

Sol. **[A]**

Isochoric process dV = 0

W = 0

Isobaric : W = PΔV = nRΔT

adiabatic : W = $\frac{nR(T_i - T_f)}{\gamma - 1}$

$|W| = \frac{nR\Delta T}{\gamma - 1}$

$0 < \gamma - 1 < 1$

Q.23 Two moles of monoatomic gas is mixed with one mole of diatomic gas at the same temperature. Molar heat capacity at constant volume for the mixture is -

(A) $\frac{13R}{6}$ (B) $\frac{11R}{6}$

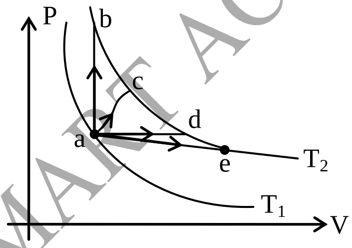
(C) $\frac{5R}{3}$ (D) $\frac{7R}{6}$

Sol. **[B]**

$$\frac{n_1 c_{v_1} + n_2 c_{v_2}}{n_1 + n_2} = (c_v)_{mix} = \frac{2\times\frac{3}{2}R + 1\times\frac{5}{2}R}{2+1} = \frac{3R + \frac{5}{2}R}{3}$$

$= \frac{11R}{6}$

Q.24 The figure shows two isotherms at temperatures T_1 and T_2. A gas is taken from one isotherm to another isotherm through different processes. Then change in internal energy ΔU has relation -



(A) $\Delta U_{ab} > \Delta U_{ac} > \Delta U_{ad} > \Delta U_{ae}$
(B) $\Delta U_{ab} = \Delta U_{ac} > \Delta U_{ad} > \Delta U_{ae}$
(C) $\Delta U_{ab} = \Delta U_{ac} = \Delta U_{ad} = \Delta U_{ae}$
(D) $\Delta U_{ab} < \Delta U_{ac} < \Delta U_{ad} < \Delta U_{ae}$

Sol. **[C]**

Internal energy depends only on state but not on the process. Hence its change is same for all the processes between two same states.

Q.25 An ideal gas whose adiabatic exponent is γ is expanded so that the amount of heat transferred to the gas is equal to the decrease of its internal energy. Molar heat capacity of the gas for this process is -

(A) $\frac{R}{1-\gamma}$ (B) $\frac{R}{\gamma - 1}$

(C) R (D) R/2

Sol. **[A]**

dQ = – dU

$nCdT = -nC_V dT$

$C = -C_V = -\frac{R}{\gamma - 1}$

$$\boxed{C = \frac{R}{1-\gamma}}$$

Q.26 The molar heat capacity for a process is : $C = \frac{R}{\gamma - 1} + \frac{\alpha}{T}$, then process equation is -

(A) $Ve^{-(\alpha/R)T}$ = constant

(B) $Ve^{(\alpha/R)T}$ = constant

(C) VT = constant

(D) $Ve^{\alpha/RT}$ = constant

Sol. **[D]**

$$\boxed{C = C_V + \frac{PdV}{dT}}$$

$\frac{PdV}{ndT} = \frac{\alpha}{T}$

$\frac{nRT}{nv}\frac{dV}{dT} = \frac{\alpha}{T}$

$\int \frac{dV}{V} = \frac{\alpha}{R}\int \frac{dT}{T^2}$

$\ell nV = -\frac{\alpha}{RT} + \ell n\, C$

$\frac{V}{C} = e^{-\alpha/RT}$

$Ve^{\alpha/RT} = C$

Q.27 The volume of a gas increase by 0.5 m^3 at a constant pressure of 1000 N/m^2. The work done by the gas is –

(A) 500 J (B) 250 J

(C) 200 J (D) 100 J **[A]**

Q.28 The amount of external work done in reducing the volume of an ideal gas by 2.4×10^{-4} m^3 at normal temperature and constant normal pressure

($1.0 \times 10^5 N/m^2$) will be –

(A) 2.4 J (B) 0.24 J

(C) 24 J (D) 240 J **[C]**

Q.29 In a cyclic process, the internal energy of gas –

(A) increases (B) decreases

(C) remains constant (D) becomes zero **[C]**

Q.30 100 Joule heat is given to a thermodynamic system and the work done by the system is 50 joule. The change in the internal energy of the system is –

(A) 100 Joule (B) 150 Joule

(C) 50 Joule (D) 200 Joule **[C]**

Q.31 The molar specific heat of a diatomic gas at constant volume is **–**

(A) R/2 (B) 3R/2

(C) 5R/2 (D) 7R/2 **[C]**

Q.32 For a monoatomic gas, the adiabatic relation between pressure P and volume V is –

(A) PV = constant (B) $PV^{5/3}$ = constant

(C) $PV^{7/5}$ = constant (D) $PV^{2/3}$ = constant

[B]

Q.33 For an ideal gas, in isothermal expansion, the value of $\Delta P/P$ is equal to : ($\gamma = C_p/C_v$)–

(A) $-\gamma^{1/2}\dfrac{\Delta V}{V}$ (B) $-\dfrac{\Delta V}{V}$

(C) $-\gamma\dfrac{\Delta V}{V}$ (D) $-\gamma^2\dfrac{\Delta V}{V}$ **[B]**

Q.34 If for a gas $R/C_v = 2/3$, then the gas is –

(A) monoatomic (B) diatomic

(C) triatomic (D) polyatomic **[A]**

Q.35 In a thermodynamic process the pressure of a fixed mass of gas is changed in such a manner that the gas releases 20 J of heat and 8 J of work is done on the gas. If the initial internal energy of the gas was 30 J, then the final internal energy will be –

(A) 2 J (B) 42 J

(C) 18 J (D) 58 J **[C]**

Q.36 Specific heat of a gas undergoing adiabatic change is -

(A) zero (B) infinite

(C) positive (D) negative **[A]**

Q.37 A liquid is being converted into vapours as its bp; the specific heat of liquid at this temperature will be-

(A) zero (B) infinite

(C) positive (D) negative **[B]**

Q.38 When vapour condenses into liquid -

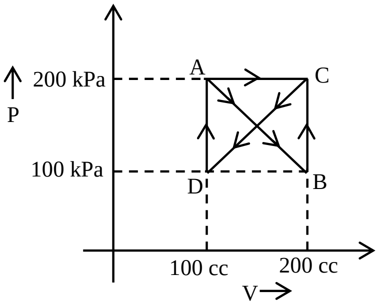
(A) it absorbs heat

(B) it liberates heat

(C) its temperature increases

(D) its temperature decreases **[B]**

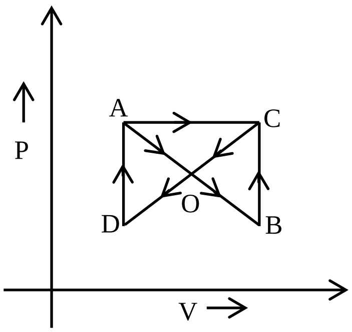
Q.39 A gas undergoes process ABCDAC. Work done by gas is –



(A) 5 kJ (B) 2.5 kJ

(C) – 5 kJ (D) 7.5 kJ **[B]**

Sol.



Work done = area (AOD) + area (AOC) – area (BOC)

= area (AOC)

= 2.5 kJ

Q.40 During an adiabatic process, the pressure of a gas is proportional to the cube of its absolute temperature. The value of C_p/C_v for that gas is –

(A) 3/5 (B) 4/3

(C) 5/3 (D) 3/2 **[D]**

Sol. For adiabatic process

$P \propto T^{(\gamma/\gamma-1)}$ (i)

Given $P \propto T^3$ (ii)

From eq. (i) & (ii)

$$\frac{\gamma}{\gamma-1} = 3 \Rightarrow \gamma = 3\gamma - 3$$

$$\gamma = 3/2$$

Q.41 A polyatomic gas ($\gamma = \frac{4}{3}$) is compressed to 1/8th its volume adiabatically. If its initial pressure is P_0, its new pressure will be –

(A) 8 P_0 (B) 16 P_0

(C) 6 P_0 (D) 2 P_0 **[B]**

Sol. PV^γ = const.

$$P_0V^{4/3} = P'\left(\frac{V}{8}\right)^{4/3}$$

$$P' = (2)^4 P_0 = 16P_0$$

Q.42 In adiabatic process, the pressure is increased by 2/3%. If γ = 3/2 then the volume decreases by nearly –

(A) $\frac{4}{9}$% (B) $\frac{2}{3}$%

(C) 1 % (D) $\frac{9}{4}$% **[A]**

Sol. For adiabatic process

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

$$\frac{\Delta P}{P} \times 100 = -\gamma\frac{\Delta V}{V} \times 100 = \frac{2}{3}$$

$$\frac{\Delta V}{V} \times 100 = -\frac{1}{\gamma} \times \frac{2}{3}$$

$$= -\frac{2}{3} \times \frac{2}{3} = -\frac{4}{9}\%$$

Q.43 A gas is expanded to double its volume by two different processes. One is isobaric and the other is isothermal. Let W_1 and W_2 be the respective work done, then –

(A) $W_2 = W_1 \ln(2)$ (B) $W_2 = \frac{W_1}{\ln(2)}$

(C) $W_2 = \frac{W_1}{2}$ (D) data is insufficient

[A]

Sol. $W_1 = P_i (V_f - V_i) = P_iV_i\left(\frac{V_f}{V_i} - 1\right)$

$= nRT (2 - 1) = nRT$

$W_2 = nRT \ln\left(\frac{V_f}{V_i}\right) = nRT \ln(2) = W_1 \ln(2).$

Q.44 Heat is supplied to a diatomic gas at constant pressure. The ratio of $\Delta Q : \Delta U : \Delta W$ is –

(A) 5 : 3 : 2 (B) 5 : 2 : 3

(C) 7 : 5 : 2 (D) 7 : 2 : 5 **[C]**

Sol. $\Delta Q = nC_P\,\Delta T = \frac{7}{2}\,nR\Delta T$

$\left(C_P = \frac{7}{2}R\right)$

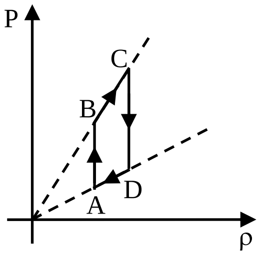
$\Delta U = nC_V\,\Delta T = \frac{5}{2}\,nR\Delta T$

$\left(C_V = \frac{5}{2}R\right)$

and $\Delta W = \Delta Q - \Delta U = nR\Delta T$

$\therefore \Delta Q : \Delta U : \Delta W = 7 : 5 : 2$

Q.45 Pressure versus density graph of an ideal gas is shown in figure –



(A) during the process AB work done by the gas is positive

(B) during the process AB work done by the gas is negative

(C) during the process BC internal energy of the gas is increasing

(D) none of these **[D]**

Sol. $\rho = \frac{PM}{RT}$ and $\rho \propto \frac{1}{V}$

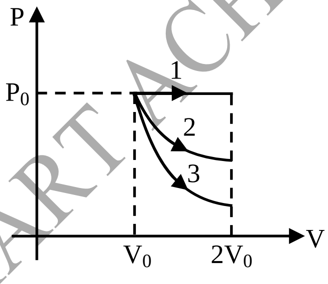
During AB, ρ and hence V is constant.

Therefore, work done is zero.

During BC, $P \propto \rho$ i.e., T

and hence, U is constant.

Q.46 A gas is expanded from volume V_0 to $2V_0$ under three different processes. Process 1 is isobaric, process 2 is isothermal and process 3 is isothermal and process 3 is adiabatic. Let ΔU_1, ΔU_2 and ΔU_3 be the change in internal energy of the gas in these three processes. Then –



(A) $\Delta U_1 > \Delta U_2 > \Delta U_3$

(B) $\Delta U_1 < \Delta U_2 < \Delta U_3$

(C) $\Delta U_2 < \Delta U_1 < \Delta U_3$

(D) $\Delta U_2 < \Delta U_3 < \Delta U_1$ **[A]**

Sol. Process 2 is an isothermal process

Hence, $\Delta U_2 = 0$

Process 1 is an isobaric (P = constant) expansion.

Hence, temperature of the gas will increase

or ΔU_1 = positive

Process 3 is an adiabatic expansion. Hence, temperature will decrease

or ΔU_3 = negative

Therefore, $\Delta U_1 > \Delta U_2 > \Delta U_3$ is the correct option.

Q.47 During adiabatic process pressure (P) versus density (ρ) equation is –

(A) $P\rho^{\gamma}$ = constant

(B) $P\rho^{-\gamma}$ = constant

(C) $P^{\gamma}\rho^{1+\gamma}$ = constant

(D) $P^{1/\gamma}\rho^{\gamma}$ = constant **[B]**

Sol. In adiabatic process

PV^{γ} = constant … (1)

density $\rho = \frac{m}{V}$

or $\rho \propto V^{-1}$

$\therefore$ Eq. (1) can be written as

$P\rho^{-\gamma}$ = constant

Q.48 One mole of an ideal gas undergoes a process $P = \frac{P_0}{1+\left(\frac{V_0}{V}\right)^2}$.

Here, P_0 and V_0 are constants. Change in temperature of the gas when volume is changed from $V = V_0$ to $V = 2V_0$ is –

(A) $-\frac{2P_0V_0}{5R}$

(B) $\frac{11P_0V_0}{10R}$

(C) $-\frac{5P_0V_0}{4R}$

(D) P_0V_0 **[B]**

Sol. At $V = V_0$, $P = \frac{P_0}{2}$

$$\therefore\ T_i = \frac{PV}{nR} = \frac{\left(\frac{P_0}{2}\right)(V_0)}{R} = \frac{P_0V_0}{2R} \qquad (n = 1)$$

and at $V = 2V_0$, $P = \frac{4P_0}{5}$

$$\therefore\ T_f = \frac{PV}{nR} = \frac{(2V_0)\left(\frac{4P_0}{5}\right)}{R} = \frac{8P_0V_0}{5R}$$

$$\therefore\ \Delta T = T_f - T_i = \left(\frac{8}{5} - \frac{1}{2}\right)\frac{P_0V_0}{R} = \frac{11P_0V_0}{10R}$$

Q.49 The relation between U, P and V for an ideal gas is

$U = 2 + 3\,P\,V$

The gas is –

(A) monoatomic

(B) diatomic

(C) polyatomic

(D) either a monoatomic or diatomic **[C]**

Sol. For an adiabatic process $dQ = 0 = dU + dW$

or $\quad 0 = dU + PdV$

From the given equation

$dU = 3\,(PdV + VdP)$

$\therefore\ 0 = 3\,(PdV + VdP) + PdV$

or $4P\,(dV) + 3V\,(dP) = 0$

or $4\left(\frac{dV}{V}\right) = -\,3\left(\frac{dP}{p}\right)$

On integrating, we get

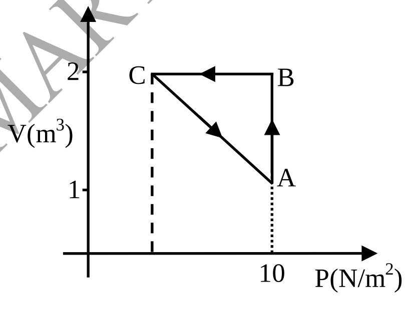
$ln(V^4) + ln(P^3) = \text{constant}$

or $PV^{4/3} = \text{constant}$

i.e., $\gamma = \frac{4}{3}$

i.e., gas is polyatomic.

Q.50 An ideal gas is taken through the cycle A → B → C → A, as shown in the figure. If the net heat supplied to the gas in the cycle is 5 J, the work done by the gas in the process C → A is –



(A) – 5 J (B) – 10 J

(C) – 15 J (D) – 20 J **[A]**

Sol. $\Delta W_{AB} = P\Delta V = (10)\,(2 - 1) = 10$ J

$\Delta W_{BC} = 0$ (as V = constant)

From first law of thermodynamics

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

$\Delta U = 0$ (process ABCA is cyclic)

$\therefore\ \Delta Q = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$

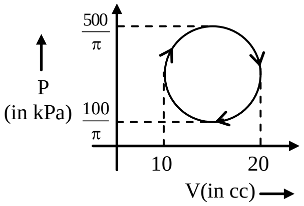
$\therefore\ \Delta W_{CA} = \Delta Q - \Delta W_{AB} - \Delta W_{BC} = 5 - 10 - 0$

$= -\,5$ J

Q.1 A steel drill making 180 rpm is used to drill a hole in a block of steel. The mass of steel block and the drill is 180 gm each. The entire mechanical work is used up in producing heat such that the rate of rise of temperature of the system is 0.5 °C/sec. If τ is the couple required to drive the drill then, find its value in SI units.
(C_{steel} = 0.10 cal/gm–°C , J = 4.186)

Sol. [4] $P = \tau W = \frac{d\theta}{dt} = (2m)\, s\, \frac{(\Delta T)}{\Delta t}$

Q.2 Work done by gas in cyclic process in Joule is.



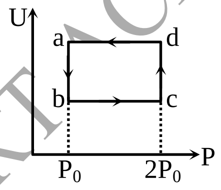
[0001]

Sol. Work done by gas

$$= \pi.\frac{\left(\frac{400}{\pi}\times 10^3\right)}{2}\times\frac{(20\times 10^{-6})}{2}\ J$$

$= 1$ J

Q.3 Figure shows the variation of internal energy (U) with the pressure (P) of 2.0 mole gas in cyclic process abcda. The temperature of gas at c and d are 300 and 500 K. The heat absorbed by the gas during the process is given by K (100)R ℓn 2. Find the value of K.



Sol. Change in internal energy for cyclic process (ΔU) = 0

for process a → b, (P = constant)

$W_{a\to b} = P\Delta V = nR\Delta T = -400\ R$

for process b → c, (T = constant)

$W_{b\to c} = -2R\ (300)\ \ell n2$

for process c → d (P = constant)

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

for process d → a, (T = constant)

$W_{d\to a} = 2R\ (500)\ \ell n2$

$\Delta W = W_{a\to b} + W_{b\to c} + W_{c\to d} + W_{d\to a}$

$\Delta W = 400R\ \ell n2$

$\Delta Q = \Delta W$

$\Delta Q = 400\ R\ \ell n\ 2 = 4(100)\ R\ \ell n2$

$\therefore$ K = 4

Q.4 The molar heat capacity for the process is xR, where R is gas constant, when 10 J of heat added to a monoatomic ideal gas, then gas performs a work of 5 J on its surrounding, then x is.

[0003]

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

$10 = \Delta U + 5 \Rightarrow \Delta U = 5J$

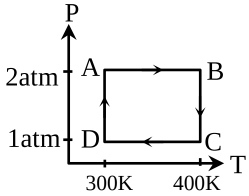
$\Rightarrow\ nC_V\Delta T = 5$ ....(1)

Now, $\Delta Q = nC\Delta T$

$10 = C \times \frac{5}{C_V}$ [from equation (1)]

or $C = 2C_V$

Q.5 Two moles of helium gas undergoes a cyclic process as shown. Assuming the gas to be ideal find the difference in heat absorbed and heat rejected by the gas.(log 2 = 0.693)



[0021]

Sol. f(2 – x) = f(2 + x) & f(20 – x) = f(x)
so f(x) (i) symmetric w.r.t x = 2
(ii) periodic with period 16
$\because$ f(0) = 5 & f(4) = 5
In every cycle at least two times f(x) = 5
so f(0) = f(16) = f(32) = f(48)… = f(160) = 5
& f(4) = f(20) = f(36) …… = f(164) = 5
so at least for 21 values of x, f(x) = 5

Q.6 Two cylinders A and B filled with pistons contain equal amounts of an ideal diatomic gas at 300 K. The piston of A is force to move, while that of B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise in temperature of the gas in B is ?

Sol. **[0042]**

$n C_p (dT)_1 = n Cv (dT)_2$

$\Rightarrow \frac{7R}{2}(30) = \frac{5R}{2}(dT)_2$

$(dT)_2 = 42$ K

Q.7 A heat engine absorbs heat at 327 ºC and exhausts heat at 127 ºC. The maximum amount of work performed by the engine in joule per kilo calorie is -

Sol. **[1400]**

$\eta = 1 - \frac{T_1}{T_2} = \frac{W}{Q} \qquad \Rightarrow 1 - \frac{2}{3} = \frac{1}{3} = \frac{W}{Q}$

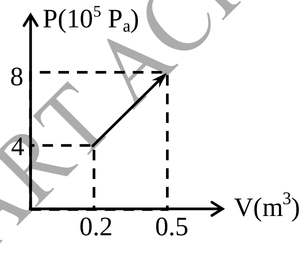
$W = \frac{1000 \times 4.2}{3} = 1400$ J

Q.8 1 g of water on evaporation at atmospheric pressure forms 1671 cm^3 of steam. Heat of vaporization at this pressure is 540 Cal/g. The increase in internal energy in cal is –

Sol. **[0500]**

$\Delta U = n C_v \Delta T$

Q.9 Upon expansion the pressure of a gas rose linearly. Quantity of heat supplied for this is x·y × 10^{5}J, where x and y are single digit number find x. The gas is monotonic.

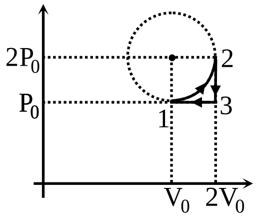


Sol.[6] $Q = \Delta U + W$

$\Delta U = \frac{Cv}{R}(P_2V_2 - P_1 V_2)$

$W = \frac{1}{2}(P_2 + P_1)(V_2 - V_1)$

Q.10 One mole of ideal monoatomic gas is taken along a cyclic process as shown in the figure. Process 1 → 2 shown is 1/4th part of a circle as shown by dotted line process 2 → 3 is isochoric while 3 → 1 is isobaric. If efficiency of the cycle is n% where n is an integer. Find n.



Sol. **[4]**

$W_{net} = (2P_0V_0) - (P_0V_0) - \frac{\pi P_0 V_0}{4}$

$W_{net} = \frac{0.86}{4} P_0V_0 = (0.22)(P_0V_0)$

Now,

$$\left.\begin{aligned} T_1 &= \frac{P_0V_0}{R} \\ T_2 &= \frac{4P_0V_0}{R} \\ T_3 &= \frac{2P_0V_0}{R} \end{aligned}\right\} \text{Thus, } \begin{aligned} \Delta U_{1\to2} &= 1 \times \frac{3R}{2}[T_2 - T_1] \\ \Delta U_{2\to3} &= 1 \times \frac{3R}{2}[T_3 - T_2] \\ \Delta U_{3\to1} &= 1 \times \frac{3R}{2}[T_1 - T_3] \end{aligned}$$

$\Delta Q_{1\to2} = (4.5)(P_0V_0) + (1.22)(P_0V_0) = (5.72)(P_0V_0)$

$\Delta Q_{3\to2} = -3P_0V_0 + 0 = -3.22)(P_0V_0)$

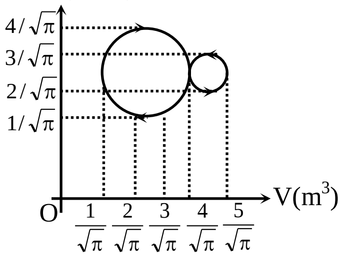
$\Delta Q_{3\to1} = -1.5(P_0V_0) - (P_0V_0) = -2.5(P_0V_0)$

Thus efficiency $\eta = \frac{W_{net}}{+\text{ve heat}}$

$$\eta = \frac{0.22(P_0V_0)}{(5.72)(P_0V_0)} = 0.04$$

Thus efficiency is 4%.

Q.11 A thermodynamic process undergoes a cyclic process as shown. Find the quantity of heat supplied to the system in one complete cycle in Joule.



Sol.[2] $\Delta Q = \Delta U + \Delta W = \Delta W \ (\because \Delta U = 0)$

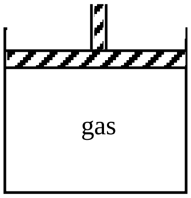
$= \pi\left[\left(\frac{3}{2\sqrt{\pi}}\right)^2 - \left(\frac{1}{2\sqrt{\pi}}\right)^2\right]$

= 2 Joule.

Q.12 A cylinder of ideal gas is closed by a 4 kg movable piston of area 30 cm^2. When the gas is heated from 50ºC to 100ºC, the piston raises 20 cm. The piston is then held in place and the gas is cooled back to 50ºC. If Q_1 is the heat added to the gas in the heating process and Q_2 is the heat lost during cooling, then $(Q_1 - Q_2)$ can be approximated as 10 λJ, where λ is an integer between (0 to 9). Find λ.

Given : $P_{atm} = 1 \times 10^5$ N/m^2

$g = 9.8$ m/sec^2



Sol.[7] During heating $P = \frac{4 \times 9.8}{30 \times 10^{-4}} + 1 \times 10^5$

$= 1.13 \times 10^5$ N/m^2

$Q_1 = \Delta U_1 + \Delta W_1 = \Delta U_1 + P\Delta V = \Delta U_1 + 68J$

During cooling $\Delta W = 0$

$Q_2' = \Delta U_2 = \Delta U_1$ (Heat supplied)

$\therefore$ Heat lost

$Q_2 = -Q_2' = \Delta U_1$

$\therefore Q_1 - Q_2 = (\Delta U_1 + 68) - (\Delta U_1) = 68J \approx 70$ J

Q.13 A movable conducting piston is inserted in a cylinder closed on both ends. One end of the cylinder contains m grams of a certain gas and the other 2m grams of the same gas. Find the ratio of volume occupied by 2m grams of the gas to the volume occupied by m grams of the gas.

Sol. **[2]** $\frac{P_2V_2}{T_2} = 2\frac{P_1V_1}{T_1}$

$P_1 = P_2$, $T_1 = T_2$,

$V_2 = 2V_1$

$\frac{V_2}{V_1} = 2$

Q.14 A piston – cylinder device with air at an initial temperature of 30ºC undergoes an expansion process for which pressure and volume are related as given below.

P(KPa)	100	25	6.25
V(m^3)	0.1	0.2	0.4

The work done by the system is n × 10^3J. Find n.

Sol. **[5]** $P_1V_1^n = P_2V_2^n = P_3V_n^n$

$100 \times (0.1)^n = 25 \times (0.2)^n$

$25 \times (0.2)^n = (6.25)\,(0.4)^n$

$n = 2$

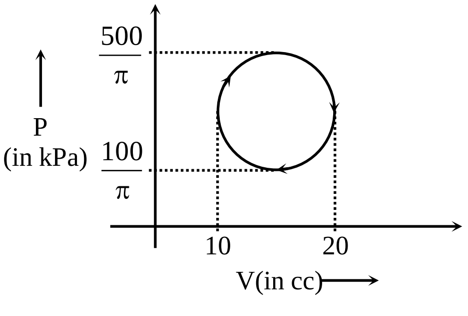
$$W = \frac{P_1V_1 - P_2V_2}{n-1} = \frac{(100 \times 0.1 - 25 \times 0.2) \times 10^3}{2-1}$$

$$= 5 \times 10^3 \text{ J}$$

Q.15 One mole of N_2 gas is maintained at room temperature (20 ºC) and at a pressure of 5 atm. It is allowed to expand adiabatically and quasi-statically until its pressure equals the room pressure of 1 atm. It is then heated at constant pressure until its temperature is again 20 ºC During this heating the gas expands. After it reaches room temperature, it is heated at constant volume until its pressure is 5 atm. It is then compressed at constant pressure until it is back to its original volume. Net heat released by the gas is n × 100 J. Find n.

Sol. **[0065]** n = 65

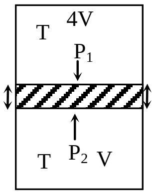
Q.16 If work done by gas in cyclic process in Joule is W, then W/200 is -



Sol. [5]

Q.17 A freely moving piston divide a vertical cylinder closed at both ends, into two parts each containing 1 mole of air. In equilibrium at T = 300K, volume of the upper part is 4 times greater than the lower part. At temperature T Kelvin the ratio of these volume be equal to 2. Value of T is .....× 150 Kelvin.

Sol.[5]



$\frac{PV}{RT}$ = constant and it is same for both part

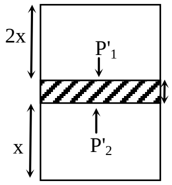
$\therefore P_1 = P_2$

$$\frac{P_1\times 4V}{T} = \frac{P_2\times V}{T} \Rightarrow \boxed{P_2 = 4P_1}$$

$$P_1A + mg = P_2A \Rightarrow P_2 = P_1 + \frac{mg}{A}$$

$$P_2 = P_1 + \frac{mg}{A} \Rightarrow P_1 + \frac{mg}{A} = 4P_1$$

$$\boxed{3P_1 = \frac{mg}{A}}$$



$$3x = 5V \Rightarrow x = \frac{5V}{3} \Rightarrow 2x = \frac{10}{3}V$$

$$\frac{P_1\times 4V}{300} = \frac{P'_1\times 2x}{T} \Rightarrow \frac{P_2\times V}{300} = \frac{P'_2\times x}{T}$$

$$P'_1A + mg = P'_2A \Rightarrow P'_2 = P'_1 + \frac{mg}{A}$$

$$P'_1 \times 2x = P'_2x \Rightarrow P'_2 = 2P'_1 \Rightarrow P'_1 = \frac{mg}{A}$$

$$\frac{mg\times 4V}{3A\times 300} = \frac{Mg}{A}\times\frac{10V}{3T}$$

$$T = \frac{3000}{4} \Rightarrow T = 750\text{ K}$$

Q.18 For a thermodynamic process, the pressure, volume and temperature are related as $P = \frac{\alpha T^2}{V}$ where α is a positive constant. The work done by this system in a constant pressure process is $K\alpha T_0^2$, if the temperature changes from T_0 to $2T_0$. Determine K.

Sol.[3] $PV = \alpha T^2$

$PdV + VdP = 2\alpha TdT$

as pressure is constant

$dP = 0$

$PdV = 2\alpha TdT$

$$W = \int PdV = \int_{T_0}^{2T_0} 2\alpha TdT = 3\alpha T_0^2$$

Q.19 Two cylinder A and B fitted with pistons contain equal amounts of an ideal diatomic gas at 300K. The piston of A is free to move, while that of B held fixed. The same amount of heat is given to the gas in each cylinder Determine the greatest integral value of the ratio of change in temperature of B to the change in temperature of A.

Sol.[1] For cylinder A process is isobaric while for B, it is isochoric.

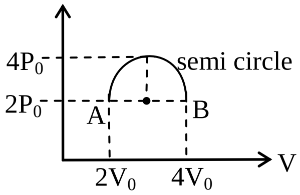
For A, $Q_A = nC_p\,\Delta T_A$, For B, $Q_B = nC_V\,\Delta T_B$

$Q_A = Q_B$ (given)

$nC_p\,\Delta T_A = nC_V\,\Delta T_B$

$$\frac{\Delta T_B}{\Delta T_A} = \frac{C_p}{C_V} = 1.4 = 1$$

Q.20 One mole of an ideal gas (monoatomic) is taken through a thermodynamic process shown in the P – V diagram. The heat supplied to the system in this process is $K(\pi + 10)\,P_0V_0$. Determine value of K.



Sol.[1] W by gas $= \frac{\pi}{4}[2V_0\times 4P_0]\times\frac{1}{2} + 2V_0\times P_0\times 2$

$= (\pi + 4)\,P_0V_0$

$\Delta V = nC_V\,\Delta T = \frac{3R}{2}(T_B - T_A)$

$= \frac{3R}{2}[2P_0\times 4V_0 - 2P_0\times 2V_0] = 6P_0V_0$

$\Delta Q = \Delta U + W = (\pi + 10)P_0V_0$