PHYSICS

The following questions given below consist of an "Assertion" (A) and "Reason" (R) Type questions. Use the following Key to choose the appropriate answer.

(A) If both (A) and (R) are true, and (R) is the correct explanation of (A).

(B) If both (A) and (R) are true but (R) is not the correct explanation of (A).

(C) If (A) is true but (R) is false.

(D) If (A) is false but (R) is true.

Q. 1 **Assertion:** We can change the temperature of a body without giving (or taking) heat to (or from) it. **Reason :** According to principle of conservation of energy, total energy of a system should remain conserved.

Sol. **[C]**

Assertion is true and reason is false.

We can change the temperature of a body without giving (or taking) heat to (or from) it. For example, in an adiabatic compression temperature rises and in an adiabatic expansion temperature falls, although no heat is given (or taken) from the system in the respective changes.

Q.2 **Statement - I :** The specific heat of a gas in an adiabatic process is zero and in an isothermal process is infinite.

Statement - II : Specific heat of gas is directly proportional to change in heat & inversely proportional to change in temperature.

Sol. **[A]** $C = \dfrac{\Delta Q}{n\Delta\theta}$

In adiabatic process, $\Delta Q = 0 \Rightarrow C = 0$

In isothermal process $\Delta\theta = 0 \Rightarrow C = \infty$

Q.3 **Assertion (A) :** Specific heat of gas at constant pressure is greater than its specific heat at constant volume.

Reason (R) : At constant pressure, some heat is spent in expansion of the gas.

Sol.[A] No volume change in isochoric process so

$\Delta Q = \Delta u$ (only)

Q.4 **Assertion :** On a T-V graph (T on y-axis), the curve for adiabatic expansion would be a monotonically decreasing curve.

Reason : The slope of an adiabatic process represented on T-V graph is always +ve.

Sol. **[C]**

$T V^{\gamma-1} = $ const.

$T (\gamma - 1) V^{\gamma} dv + V^{\gamma-1} dT = 0$

$\dfrac{T}{V} (\gamma - 1) dV + dT = 0$

$\dfrac{dT}{dV} = -\dfrac{T}{V} (\gamma - 1)$

Slope is negative $\boxed{\dfrac{dT}{dV} < 0}$

Q.5 rectangular hyperbola. Then P-T graph in the same process will be a parabola.

Reason (R) : If V-T graph is rectangular hyperbola, then V decrease when pressure increase.

Sol.[B] $VT = const, PV^2 = const, \dfrac{P}{T^2} = const$

Q.6 **Assertion :** Water cannot be liquefied at a temperature greater than 374.1ºC, no matter how large the pressure is.

Reason : The critical temperature of water is 374.1ºC. Water in its gas form at a temperature lower than 374.1ºC is called water vapour and above 374.1ºC is called water gas.

Sol.[A] Water cannot be liquefied at a temperature greater than its critical temperature (374.1ºC), no matter haw large the pressure is. Water in its gas form at a temperature lower than its critical temperature is called water vapour and above it is called water gas.

Q.7 **Assertion :** Air quickly leaking out of a balloon becomes cooler.

Reason : In Adiabatic expansion temperature increases.

Sol. **[C]**

$\lambda_m T = $ constant

rapid process

Q.8 **Statement - I :** The isothermal curves intersect each other at a certain point.

Statement - II : The isothermal change takes place slowly, so, the isothermal curves have very little slope.

Sol. **[D]** Statement-I is incorrect

∵ Two isothermal curve can never intersect each other but statement - II is correct

Q.9 **Statement -1 :** In an isochoric process the work done is zero. and

Statement – 2 : The work done $\Delta W = \int_{V_i}^{V_f} PdV$

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

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

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

(D) Statement-1 is true, Statement-2 is false B

[B]

Sol. **Statement I**

$W = \int P.dv$ \qquad [at V = const.]

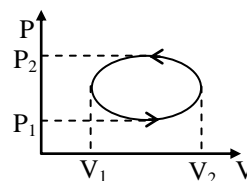$dv = 0$

∴ $\boxed{W = 0}$ → Correct

Statement-II

Work done

$W = \int_{V_1}^{V_2} P.dv$

Q.10 **Statement I :** The efficiency of a Carnot cycle depends on the nature of gas used.

Statement II : Workdone in adiabatic process depends on nature of gas, and adiabatic is a part of Carnot cycle. **[D]**

Q.11 **Statement I :** Work done in a cycle process as shown in figure. $W = \pi (P_2 – P_1)(V_2–V_1)$.

Statement II : Magnitude work done for cyclic process is equal to the area enclosed by the P-V diagram. **[D]**

Q.12 **Statement I :** The average degree of freedom per molecule for a gas is 6. If gas performs 25 J of work when it expands at a constant pressure then the heat absorbed by the gas is 100 J.

Statement II : First law of thermodynamics is $dQ = \Delta U + dW$ where $\Delta U = nC_v dT$. **[A]**

Q.13 **Statement I :** Temperature of body can be rised without heating.

Statement II : As the heat is continuously generated by electric heater, the temperature of heater rises continuously. **[C]**

Q.14 **Statement I :** It is possible that there is a change in temperature of a body without giving or taking heat from the system.

Statement II : Internal energy is a function of temperature. **[B]**

Q.15 **Statement I :** In the process $V = \dfrac{K}{T}$, if the volume of gas increases, then workdone by gas decreases.

Statement II : Workdone in the above process is $dW = – nR dT$ **[D]**

Q.16 **Statement I :** Room will be cooled by leaving the door of an electric refrigerator open.

Statement II : Refrigerator extracts heat from freezing chamber and rejects heat into the surrounding air. **[D]**

Q.17 **Assertion:** Work done by a gas in isothermal expansion is more than the work done by gas in the same expansion adiabatically.

Reason: Temperature remains constant in isothermal process and not in adiabatic process. **[B]**

Q.18 **Assertion :** A gas have a unique value of specific heat capacity.

Reason : Specific heat capacity is heat required to raise the temperature of unit mass of the substance by unity. **[D]**

Sol. A gas have may values of specific heat capacity depending on the process used.

Q.19 **Assertion (A) :** During an adiabatic expansion temperature of gas must decrease.

Reason (R) : During adiabatic process $TV^{\gamma-1} = $ constant, $\gamma \rightarrow$ adiabatic exponent of gas.

[A]

Sol. If V increases temperature of gas decreases.

Q.20 **Assertion (A) :** The molar heat capacity of an ideal gas at constant volume can never be negative.

Reason (R) : At constant volume, the heat supplied to the gas increases its internal energy and this increases the temperature. **[A]**

PHYSICS

Q.1 An ideal monatomic gas undergoes different types of processes which are described in column-I match the corresponding effects in column-II. The letters have usual meaning.

Column-I	Column-II
(A) $P=2V^2$	(P) If volume increases then temperature will also increase
(B) PV^2=constant	(Q) If volume increases then temperature will decrease
(C) $C=C_V+2R$	(R) For expansion, heat will have to be supplied to the gas
(D) $C=C_V-2R$	(S) If temperature increases then work done by gas in positive

Sol. (A) P,R,S   (B) Q
(C) P,R,S   (D) Q,R

(A) If $P = 2V^2$, from ideal gas equation we get
$2V^3 = nRT$
∴ with increase in volume

(i) Temperature increases implies $dU = +ve$
(ii) $dw = +ve$
Hence $dQ = dU + dw = +ve$

(B) If PV^2 = constant, from ideal gas equation we get $VT = k$ (constant)
Hence with increase in volume, temperature decreases
Now $dQ = dU + PdV = nC_v dT - PK/T^2 dT$
$[\because dV = -K/T^2 dT]$
$= nC_V dT - PV/T dT = n(C_V-R)dT$
∴ with increase in temperature $dT = +ve$ and since $C_V > R$ for monoatomic gas. Hence $dQ = +ve$ as temperature is increased

(C) $dQ = nC dT = nC_v dT + PdV$
$\Rightarrow n(C_v + 2R) dT = nC_v dT + PdV$
∴ $2nRdT = PdV$ ∴ $dV/dT = +ve$
Hence with increase in temperature volume increase and vice versa
∴ $dQ = dU + dw = +ve$

(D) $dQ = nC dT = nC_v dT = PdV$
or $n(C_v-2R)dT = nC_v dT + PdV$
or $-2nRdT = PdV$ ∴ $dV/dT = -ve$
∴ with increase in volume temperature decreases. Also $dQ = n(C_v-2R) dT$
with increase in temperature $dT = +ve$ but $C_v < 2R$ for monoatomic gas. Therefore $dQ = -ve$ with increase in temperature.

Q.2 One mole of diatomic gas is taken through below cyclic process. The process CA is defined as $P =$ (constant) V^2. Temperature at C is 300 K. Match the quantities in Column I to those in Column II.
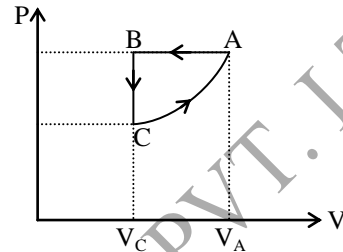
Column-I	Column-II
(A) Work done in path CA is	(P) 1200 R
(B) Work done in path AB is	(Q) 2250 R
(C) Change in internal energy in path BC is	(R) 700 R
(D) Heat transferred in path AB is	(S) 4200 R

(A) → R   **(B)** → P   **(C)** → Q   **(D)** → S

Q.3 One mole of ideal monatomic gas is taken through the cyclic process ABCDA as shown in figure. Match the Quantities in column I with that of column II
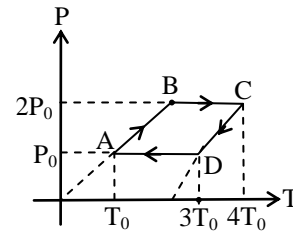
Column I	Column II
(A) work done in process BC	(P) $-3/2 RT_0$
(B) Change in internal energy in CD	(Q) $3/2 RT_0$
(C) Heat transferred in in process DA	(R) $-5RT_0$
(D) Heat transferred in in process AB	(S) $2 RT_0$

Sol. $A \to S ; B \to P ; C \to R ; D \to Q$

AB : isochoric process

$T_B = 2T_0$

work done in BC : (isobaric)

$$W = P\Delta V = n\,R\Delta T$$

$$W = nR\,(4T_0 - 2T_0)$$

$$W = (1)\,2RT_0$$

$$W_{BC} = 2RT_0$$

Internal energy change in CD

CD : $\Delta U_{CD} = nC_v(T_D - T_C)$

$$= (1)\,\frac{3}{2}\,R\,(3T_0 - 4T_0)$$

$$= -\frac{3}{2}\,RT_0$$

Heat transferred in DA : isobaric

$$Q = nC_p\,\Delta T$$

$$= (1)\left(\frac{\gamma}{\gamma - 1}\right)(T_0 - 3T_0)$$

$$= \frac{5/3R}{2/3} \times (-2T_0)$$

$$= -5RT_0$$

Heat transferred in AB (isochoric)

$$Q = \Delta U + W$$

$$W = 0$$

$$Q = \Delta U = nC_V(T_B - T_A)$$

$$Q = (1)\,\frac{3}{2}\,R\,(2T_0 - T_0)$$

$$Q = \frac{3}{2}\,RT_0$$

Q.4 In column I some statements/phrases/terms are given and in column II are given some physical quantities. Match the entries of column I with the entries of column I with the entries of column II.

Column-I	Column-II
(A) State variable	(P) Pressure
(B) connot be defined in non equilibrium state	(Q) internal energy
(C) Extensive state variable	(R) Temperature
(D) Intensive state variable	(S) Heat

Sol. $A \to P,Q,R$; $B \to P,Q,R,S$; $C \to Q$; $D \to P,R$

For A : heat is not s state variable as we cannot say that heat of a body is this much, heat is actually energy in transit. It is not used to characterize the state.

For B : In non-equilibrium state, we cannot assign any value to pressure, volume, temperature, internal energy etc. (i.e. state variables). But heat is the energy in transit which can be computed from the fact that how much energy is transferred, but from $Q = ncdT$. if temperature is not defined, then heat also cannot be defined.

For C : Extensive state variables indicate the size of the system

For D : Intensive state variables do not indicate the size of the system, like pressure and temperature.

Q.5

Column-I	Column-II
(A) Isobaric process	(P) $dQ = 0$, $\lvert dW \rvert > dW_{isochoric}$
(B) Isothermal process	(Q) $dW = 2.303\,nRT\,\log\left(\dfrac{P_i}{P_f}\right)$
(C) Adiabatic process	(R) $\lvert dW_{adi}\rvert < \lvert dW_{iso}\rvert$ since volume varies
(D) Isochoric process	(S) $\lvert dW \rvert$ is maximum
	(T) $dW = 0$

Sol. $(A) \to (S)$, $(B) \to (Q)$, $(C) \to (P)$ & (R), $(D) \to (T)$

For any system, the work done is maximum when a Isobaric process is carried as the graph will be parallel to the volume axis.

So, $(A) \to (S)$.

In an isothermal process, $dT = 0$ and

$$dW = 2.303\,nRT\,\log\left(\frac{V_f}{V_i}\right)$$

or $2.303\,nRT\,\log\left(\dfrac{P_i}{P_f}\right)$ as $P_iV_i = P_fV_f$

So, $(B) \to (Q)$.

In adiabatic processes, $dQ = 0$ and the magnitude of work done which is area below the graph will be more than that of an isochoric process where $dW = 0$.

So, $(C) \to (P)$.

In Isothermal process the variation of P – V will not be as steeper as that of an adiabatic process.

So, $(C) \to (R)$

In Isochoric process, $dV = 0$. So $dW = 0$ and $(D) \to (T)$.

Q.6

Column-I	Column-II
(A) Change of state	(P) Work done and change in internal energy are zero
(B) Complete Reversible process	(Q) Temperature is constant
(C) Heat content of the container	(R) Coexistence of two states in thermal equilibrium
(D) Iosthermal process	(S) Water equivalent

Sol. **(A) → (R) & (Q), (B) → (P), (C) → (S), (D) → (Q)**

Change of state always happens at the same temperature and there is thermal equilibrium maintained at that temperature between the states.

So, (A) → (R) & (Q)

Complete reversible process involves retaining the thermodynamical variables at the end as it was at the beginning and also the path is retraced.

So, (B) → (P)

When heat content of a container is to be accounted, we need its water equivalent.

So, (C) → (S)

In an isothermal process $\Delta T = 0$,

So, $\Delta U = 0$

but work done is $2.303 \, nRT.\log\left(\dfrac{V_f}{V_i}\right)$.

So, (D) → (Q)

Q.7 ΔW-represents work done by the system and ΔQ represents heat absorbed by the system $(T_A < T_D)$
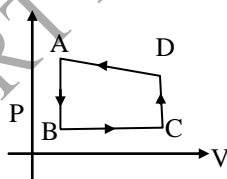
Column I	Column II
(A) AB	(P) $\Delta W > 0$
(B) BC	(Q) $\Delta W < 0$
(C) CD	(R) $\Delta Q > 0$
(D) DA	(S) $\Delta Q < 0$

Ans. **A → S ; B → P, R ; C → R ; D → Q,S**

Q.8 For various thermodynamic processes, match the following -

Column I	Column II
(A) Isochoric Heating	(P) $\Delta Q > O$
(B) Isobaric Expansion	(Q) $\Delta W > O$
(C) Isothermal Expansion	(R) $\Delta U > O$
(D) Adiabatic Expansion	(S) $\Delta W > O$

Ans. A → P,R ; B → P, Q, R; C → P,Q; D → Q

Q.9

Column I	Column II
(A) Temperature	(P) $\dfrac{f}{2}RT$
(B) Equipartition law	(Q) Measure of average of energy molecular translational K.E.
(C) Translational K.E. for all one mole ideal gas	(R) same for all degrees of freedom
(D) Internal energy of an ideal gas	(S) $\dfrac{3}{2}RT$

Ans. A → Q; B → R ; C → S ; D → P

Q.10 A sample of gas undergoes a transition from an initial state *'a'* to a final state *'b'* by three different paths (processes), as shown in the p-V diagram in Figure. Based on diagram match the following-
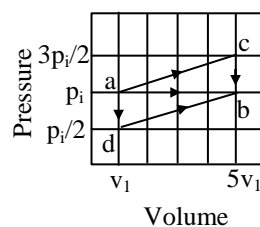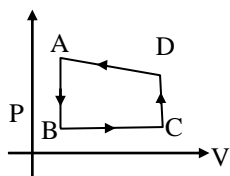

Column I	Column II
(A) Varying Pressure	(P) in process *'ac'*
(B) Varying Volume	(Q) in process *'cb'*
(C) Varying Temp.	(R) in process *'ab'*
(D) Decrease in internal Energy	(S) in process *'db'*

Ans. A → P,Q,S ; B → P,R, S ; C → P,Q,R,S ; D → Q

Q.11 ΔW-represents work done by the system and ΔQ represents heat absorbed by the system -

Column I	Column II
(A) AB	(P) ΔW > 0
(B) BC	(Q) ΔW < 0
(C) CD	(R) ΔQ > 0
(D) DA	(S) ΔQ < 0

Ans. A → S ; B → P, R ; C → R ; D → Q, S

Q.12

Column I	Column II
(A) Adiabatic expansion	(P) No work done
(B) Isobaric expansion	(Q) Constant internal energy
(C) Isothermal expansion	(R) Increase in internal energy
(D) Isochoric process	(S) Decrease in internal energy

Ans. A → S; B → R; C → Q; D → P

Q.13 Consider the an ideal gas to be taken along a process. Then during the process -

Column -I	Column-II
(A) Work done by an ideal gas	(P) Path dependent
(B) Internal energy of the ideal gas	(Q) State function
(C) Molar heat capacity	(R) Path independent
(D) Heat absorbed or rejected by an ideal gas.	(S) May be zero

Sol. A → P,S ; B → Q,R, S ; C → P,S ; D → P,S

$\Delta U = Q - W$

Q and W both are path function.

Q.14 A sample of gas goes from state A to state B in four different manners, as shown by the graphs. Let W be the work done by the gas and ΔU be change in internal energy along the path AB. Correctly match the graph with the statements provided.
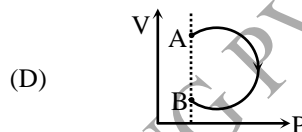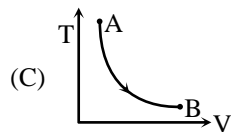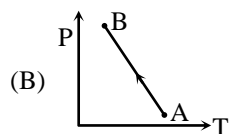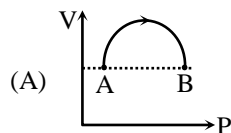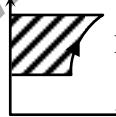
Column-I	Column-II
(A)	(P) Both W and ΔU are positive
(B)	(Q) Both W and ΔU are negative
(C)	(R) W is positive whereas ΔU is negative
(D)	(S) W is negative whereas ΔU is positive

Sol. A → S ; B → Q ; C → R ; D → Q

In (A), V is on vertical axis.

 Part-I As V is increasing, W is positive.

As negative work in part-II is greater than positive work in part-I, net work during the process is negative. Using PV = nRT and as V$_{remains}$ same for initial and final points of the process, it is obvious that final temp. is greater than initial temperature as.

Q.15 Match the following -

Column-I	Column-II
(A) Degree of freedom	(P) $2/(\gamma - 1)$
(B) The ratio of molar heat capacity at constant pressure to universal gas constant R	(Q) $r\gamma$
(C) Slope of P-V graph in isothermal process	(R) $\dfrac{\gamma}{\gamma - 1}$
(D) Adiabatic bulk modulus	(S) $-P/V$

Sol. A → R ; B → P ; C → S ; D → Q

Q.16 One mole of a diatomic gas is compressed to one fourth of its original volume v_0 according to the law $VT^2 = $ constant. The initial pressure is P_0. Match column for this process.

Column-I	Column-II
(only magnitude of change)	
(A) $\|\Delta Q\|$	(P) $7 P_0 V_0$
(B) $\|\Delta U\|$	(Q) $2 P_0 V_0$
(C) $\|\Delta W\|$	(R) $2.5 P_0 V_0$
(D) $\|(\Delta P).V_0\|$	(S) $0.5 P_0 V_0$

Sol. A → S ;   B → R ;   C → Q;   D → P

Q.17 Column I contains different processes undergone by a diatomic ideal gas. Column II change in different parameter of ideal gas.

Column-I	Column-II
(A) $PV^{-1} = $ const. and volume is increased twice	(P) Heat is given to gas
(B) $P^2 V = $ const and pressure is increased twice	(Q) Heat is rejected by gas
(C) $PV^{6/5} = $ const and volume is reduced to half the initial volume	(R) Work done by gas is negative
(D) $PV^2 = $ const and pressure is increased 3 times	(S) No change in internal energy
	(T) Internal energy Increase

Sol.

$$A \to P,T \; ; \; B \to Q,R \; ; \; C \to Q,R,T; \; D \to P,R,T$$

For process $PV^n = $ const.

Molar heat capacity of gas

$$C = R\left(\frac{1}{\gamma-1} - \frac{1}{n-1}\right), \gamma = \frac{7}{5} \qquad \text{...(i)}$$

$$PV = nRT = \frac{const}{V^{n-1}} = const \times P^{\left(1-\frac{1}{n}\right)}$$

For n = –1 : Temperature increase with increase in volume $\therefore$ work done +ve
Hence heat is absorbed by system.

For n = 1/2 : Temperature and volume decrease with increase in pressure
$\therefore$ Work done –ve
Hence heat is rejected.

For n = 6/5 : Temperature increases with decrease in volume $\therefore$ work done –ve
Hence heat is rejected.

For n = 2 : Temperature increase with increase in pressure $\therefore$ work done –ve
Hence heat is absorbed.

Q.18 Match the following -

Column-I	Column-II
(A) Temperature of a gas	(P) Internal energy increases
(B) Work done by the gas	(Q) Intermolecular force decreases
(C) Thermal expansion	(R) Path function
(D) Mechanical Compression	(S) State function

Sol. A → S ;   B → R ;
**C → Q ;   D → P**

Q.19 Match the following -

Column-I	Column-II
(A) Degree of freedom	(P) $2/(\gamma - 1)$
(B) The ratio of molar heat capacity at constant pressure to universal gas constant R	(Q) γP
(C) Slope of P – V graph in isothermal process	(R) $\dfrac{\gamma}{\gamma-1}$
(D) Adiabatic bulk modulus	(S) $-P/V$

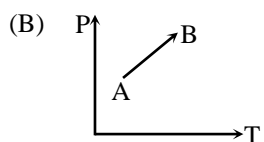**Sol. A→R   ;   B→P   ; C→S   ;   D→Q**

Q.20 One mole of an ideal gas is taken from state A to state B by four different process which have been shown in figure under column-I.
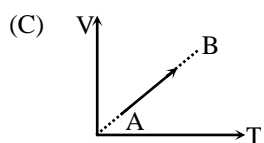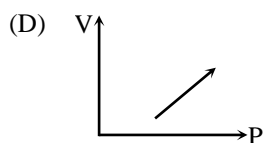
Column -I   **Column -II**
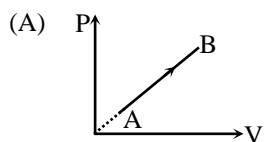
(A)   (P) Pressure increases

(B)   (Q) Volume increases

(C)   (R) Temperature increases

(D)   (S) Temperature decreases

(T) Volume decreases

1. $A \to P,Q,R$; $B \to P,Q,R$; $C \to Q,R$; $D \to P,Q,R$

(A) $P = KV$

$PV = nRT$

$KV^2 = nRT$

(B) $P = mT + C$

$1 = \dfrac{mT}{P} + \dfrac{C}{P}$

$\left(1 - \dfrac{C}{P}\right)\dfrac{1}{m} = \dfrac{T}{P}$

$PV = nRT$

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

$V = \dfrac{nR}{m}\left(1 - \dfrac{C}{P}\right)$

(D) $V = mP + C$

$PV = nRT$

$\dfrac{(V - C)}{m} V = nRT$

PHYSICS

Q.1 Consider process AB for an ideal gas and find out which of the following statement are possible. Temperature at A, C and B are T_1, T_2 and T_3. C is any point between AB.
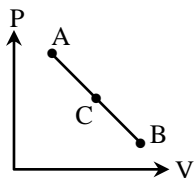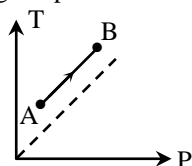

(A) $T_1 < T_3 < T_2$ (B) $T_2 > T_1 > T_3$
(C) $T_1 = T_3 < T_2$ (D) $T_3 < T_1 > T_2$

[A,B,D]

Sol. In process AB temperature first increases then decreases.

**Q. 2** Temp Vs pressure graph of an ideal gas is shown. Then during the process AB.

(A) Internal energy of the gas continuously decreases
(B) Volume of the gas increases
(C) Work done by atmosphere on the gas is + Ve
(D) Temperature is directly proportional to pressure **[C]**

Sol. Volume decreases, so work done by gas is negative.

**Q. 3** A ideal gas undergoes a cyclic process abcda which is shown by pressure-density curve -
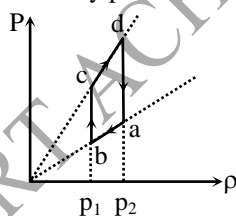
(A) Work done by the gas in the process 'bc' is zero
(B) Work done by the gas in the process 'cd' is negative
(C) Internal energy of the gas at point 'a' is greater than at state 'c'
(D) Net work done by the gas in the cycle is negative **[A,B,D]**

Sol. $P = \dfrac{\rho}{M_0} RT \Rightarrow \dfrac{P}{\rho} = \dfrac{R}{M_0} T$

Slope of the curve $\propto$ Temperature.

Hence cd and ab are isothermal processes. $P \propto \dfrac{1}{V}$
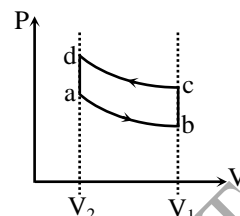
Equivalent PV- diagram

i.e. bc and da are constant volume process.

Q. 4 A certain mass of saturated water vapour is contained in a cylindrical vessel under a weightless piston at one atmospheric pressure. The piston is slowly lowered till 0.7 g of vapour gets condensed. The volume under the piston is now only $(1/5)^{th}$ of the original volume. (Neglect the volume of liquid formed). Then -

(A) original mass of the vapour was 0.89 gm
(B) original mass of the vapour was 1.14gm
(C) temperature of vapour is 100ºC
(D) temperature of vapour is 114ºC

Sol. **[A,C]**

$P_1 V_1 = n_1 RT$

P_1 = vapour pressure = P_0

If piston is lowered slowly, then the process is isothermal

$\dfrac{V_1}{n_1} = \dfrac{V_2}{n_2}$

$\dfrac{V_1}{n_1} = \dfrac{V_1 / 5}{n_2}$

$n_2 = n_1/5$

0.7 gm vapour is condensed so

$n - n_2 = \dfrac{0.7}{18}$ …(i)
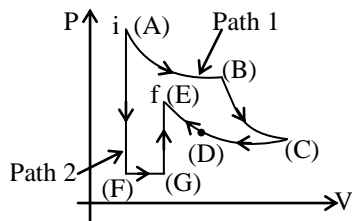
$n_1 = \dfrac{m}{18}$ …(ii)

Dividing (i) by (ii),

$\dfrac{4n_1 / 5}{n_1} = \dfrac{0.7}{m}$

$$4m = 3.5$$
$$m = \frac{3.5}{4} = 0.87$$

Q. 5 Figure shows two paths that may be taken by gas from an initial point **i** to final point **f**. Path 1 consists of an isothermal expansion (work is 50J in magnitude), an adiabatic expansion (work is 40 J in magnitude), an isothermal compression (work is 30 J in magnitude) & then an adiabatic compression (work is 25 J in magnitude) –

(A) Change in internal energy in path 2 i.e. in path AFGE is – 15 J

(B) Heat transferred in path AB is 50 J

(C) Internal energy change in path DE is – 15 J

(D) Work done is greatest in path FG

[A,B]

Q.6 Temperature of 1000 grams of nitrogen is raised from –20ºC to 100ºC at constant pressure. Given: specific heat at constant volume C_v = 5 cal/mole ºC and R = 2Cal/mole ºC

(A) Heat required in the process is 30 K Cal

(B) Increase in the internal energy of gas is 21 Kcal

(C) If process is at constant volume then heat required is 21 Kcal

(D) external work done is 10 KCal

Sol. **[A,B,C]**

(A) Heat required is -

$$Q = nCp\Delta T = n(Cv + R)\Delta T$$
$$= \frac{1000}{28} \, [5 + 2] \times 120 = 30 \times 10^3 \, cal$$
$$Q = 30 \, Kcal$$

(B) The increase in the internal energy is

$$\Delta U = nCv\Delta T = \frac{1000}{28} \times 5 \times 120$$
$$= 21 \, Kcal$$

(C) Q = nCv∆T + P∆V

for constant volume ∆V = 0
$$Q = nCv\Delta T = 21 \, Kcal$$
(D) external work done is
$$W = Q - \Delta U = 8.6 \, KCal$$

Q.7 10 litres of ideal gas at atmospheric pressure is compressed isothermally to volume of 1 litre and then allowed to expand adiabatically to 10 litres. Choose the correct options related to this -

(A) Net work is done on gas

(B) Net work is done by gas

(C) Final pressure is equal to initial pressure

(D) final pressure is less than initial pressure

Sol. **[A,D]**
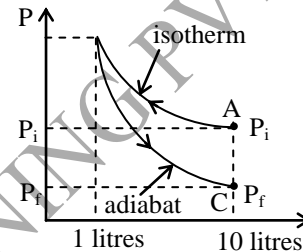
AB: isotherm
BC : adiabat
* Area under AB curve is more than BC Curve hence het work done is negative and hence work is done on system (gas). As can be seen from graph P_f final pressure is less than initial pressure P_i i.e $P_f < P_i$

Q.8 Figure shows an indicator diagram. During path 1–2–3, 100 cal is given to the system and 40 cal worth work is done. During path 1 – 4 –3, the wore done is 10 cal. Then :
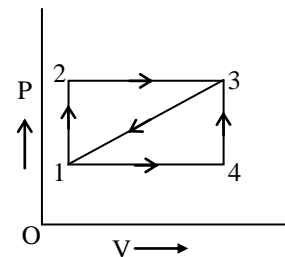
(A) heat given to the system during path 1–4–3 is 70 cal

(B) if the system is brought from 3 to 1 along straight line path 3 –1, work done is worth 25 cal

(C) along straight line path 3–1 the heat ejected by the system is 85 cal

(D) the internal energy of the system in state 3 is 140 cal above that in state 1

Sol. **[A,B,C]**

The critical step is that work in path 1-3 is mean of that for 1-2-3 and 1-4-3 (considering areas).
For (A) $100 - 40 = x - 10$ or, $x = 70$ cal.
(B) It is also correct as half of $(40 + 10)$ is 25 cal.
(C) dU is -60, work is $- 25$
So, $- 60 = dQ - (-25)$
or, $dQ = - 85$ cal
hence, option (C) is also correct.
(D) $dU = 100 - 40 = 60$ cal
Hence, option (D) is not correct.

Q. 9 Figure shows two paths that may be taken by gas from an initial point i to final point f. Path 1 consists of an isothermal expansion (work is 50 J in magnitude), an adiabatic expansion (work is 40 J in magnitude), & then an adiabatic compression (work is 25 J in magnitude) –
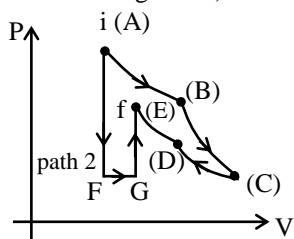
(A) Change in internal energy in path 2, i.e. n path AFGE is – 15J

(B) Heat transferred in path AB is 50 J

(C) Internal energy change in path DE is – 15 J

(D) Work done is greatest in path FG

Sol. **[A,B]**

$\Delta U_{AB} + \Delta U_{BC} + \Delta U_{CD} + \Delta U_{DE} = \Delta U_{if}$
$0 + (- W_{BC}) + 0 + (- W_{DE}) = \Delta U_{if}$
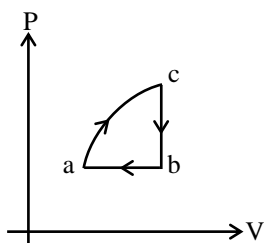$- 40 J + (- (- 25)) = \Delta U_{if}$
$- 40 + 25 = \Delta U_{if}$
$\Delta U_{if} = - 15 J$
For path AB : Isothermal process
$Q_{AB} = W_{AB} = 50$ J

Q.10 Figure shows cyclic process. From c to b 40 J is transferred as heat from b to a, 130 J is transferred as heat, and work done is 80 J from a to c, 400 J is transferred as heat then –

(A) work done in process a to c is 310 J
(B) Net work done in cycle is 230
(C) Net change in internal energy in cycle is 130 J
(D) Thermal efficiency is 57.5%

Sol. **[A,D]**

$\Delta U_{cycle} = 0$
$Q_{net} = W_{net}$
$- 40 - 130 + 400 = W_{cb} + W_{ba} + W_{ac}$
$W_{ac} = 310$ J
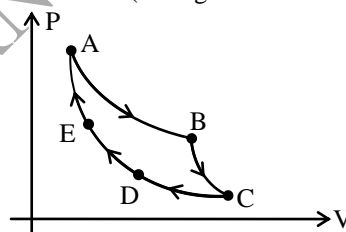
Thermal efficiency $= \dfrac{\text{work output}}{\text{Heat Input}}$

$= \dfrac{230}{400} \times 100$
$= 11.5 \times 5$
$= 57.5$

Q.11 AB : isothermal ($T_A = 300$ K)
BC : Adiabatic (Work = 5 J)
CD : Constant pressure (5 atm)
DE : Isothermal
EA : Adiabatic (Change in internal energy 8J) –

(A) work done in the cycle is 13 J
(B) change in internal energy in path CD is – 3J
(C) heat transferred in path DE is –11J
(D) work done in EA is – 8J

Sol. **[B,D]**

$\Delta U_{AB} + \Delta U_{BC} + \Delta U_{CD} + \Delta U_{DE} + \Delta U_{EA} = 0$

$0 + (- W_{BC}) + \Delta U_{CD} + 0 + (8J) = 0$

$(- 5J) + \Delta U_{CD} + (8J) = 0$

$\Delta U_{CD} = - 3J$

$Q_{AB} + Q_{BC} + Q_{CD} + Q_{DE} + Q_{EA}$
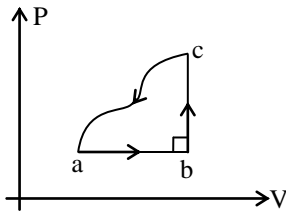
$\quad = W_{AB} + W_{BC} + W_{CD} + W_{DE} + W_{EA}$

$(Q_{CD} - W_{CD}) + Q_{EA} = W_{BC} + W_{EA}$

$- 3J - W_{BC} = W_{EA}$

$- 3J - 5J = W_{EA}$

$W_{EA} = - 8J$

Q.12 A gas is taken through a cyclic process. The change in internal energy along the path from c to a is – 160 J. Heat transferred along the path from a to b is 200 J and 40 J from path b to c. Then -

(A) work done in the cycle is less than 80 J

(B) work done in path abc is 80 J

(C) work done in path ab is 160 J

(D) net heat transferred is less than 80 J

Sol. **[A,B,D]**

For cyclic process $Q_{net} = W_{net}$ since $\Delta U_{cycle} = 0$

$Q_{ab} + Q_{bc} + Q_{ca} = W_{ab} + W_{bc} + W_{ca}$

$200\ J + 40\ J + Q_{ca} = W_{abc} + W_{ca}$

$240\ J + Q_{ca} = W_{abc} + W_{ca}$

$240\ J + Q_{ca} – W_{ca} = W_{abc}$

$240 – 160 = W_{abc}$

$W_{ab} + W_{bc} = W_{abc} = 80\ J$

$W_{ab} + 0 = 80\ J$

$W_{ab} = 80\ J$

$W_{net} = W_{ab} + W_{bc} + W_{ca}$

Since $W_{ca} < 0$, $\qquad$ $W_{net} < 80\ J$

Q.13 A thermodynamic system returns to its original state. Quantity which is not zero -
(A) Change in pressure of system
(B) Change in internal energy of system
(C) Heat gained/lost by system
(D) Work done by system $\qquad$ **[C,D]**

Sol. Work done and hence ΔH + (heat lost/gained) is a path function.

Q.14 Figure shows 'P' vs 'T' diagram for cyclic process ABCA undergone by ideal gas. Which of the following graph is correct (U : internal energy) –

(A)

(B)

(C)
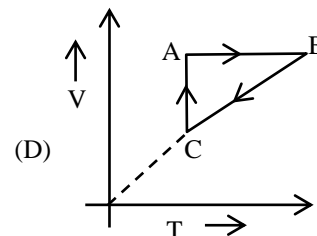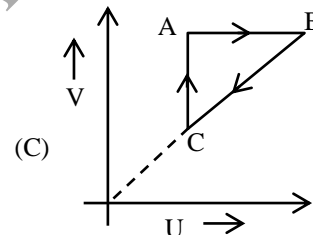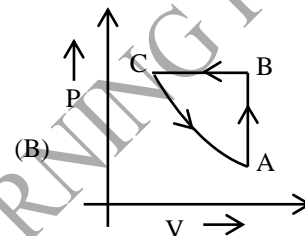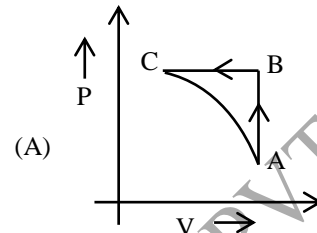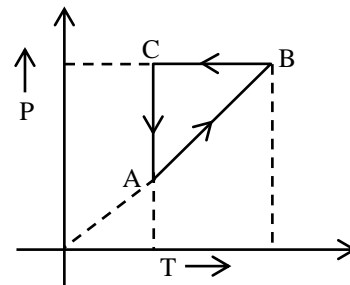
(D) $\qquad$ **[B,C]**

Sol. AB : Isochoric process with increase in P and T.

BC : Isobaric process with decrease in T and V.

CA : Isothermal process with decrease in P and hence increase in V.

Q.15 A thermally insulated thermoflask containing tea is vigorously shake. For this situation, mark the correct statement (s) -
(A) The temperature of tea rises
(B) Heat has been transferred to tea
(C) Work has been done on tea

(D) Internal energy of the tea + flask system increases

Sol. **[A,C,D]** On shaking the flask the mechanical work has been done on tea which increases the internal energy of system and hence temperature of tea rises. As thermoflask is thermally insulated so no heat transfer take place.

Q.16 Given 1 mole of an ideal monoatomic gas, in a state characterized by P_A, V_A a change occurs so that the final pressure and volume are equal to P_B, V_B where $V_B > V_A$. Select the correct statements -
(A) The work done by the gas during the process is completely determined by the values P_A, V_A, P_B and V_B
(B) The change in internal energy of the gas during the process is completely determined by the values P_A, V_A, P_B and V_B
(C) The heat supplied to the gas during the process is completely determined by the values P_A, V_A, P_B and V_B
(D) None of these

Sol.[B] Process is not known

Q.17 Heat is supplied to ice at a constant rate. Temperature variation with time is as shown is in fig. -
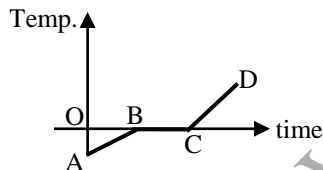
(A) During AB volume of substance increases
(B) During BC, volume of substance decreases
(C) Specific heat of substance in liquid phase is proportional to reciprocal of slope of portion AB of graph
(D) Latent heat of fusion of substance is independent of portion AB of graph

Sol.[B, D] AB is corresponding to solid; BC is corresponding to solid $\rightarrow$ liquid transition phase & CD is corresponding to liquid state.

Q.18 An ideal gas is enclosed in a vessel at initial pressure P_0 and volume V_0, Temp T_0. It is found that due to leakage gas is escaping from the vessel at a rate such that $\dfrac{dn}{dt} = -\alpha P$, α is positive constant where $\dfrac{dn}{dt}$ is the rate of change of moles, then choose the correct alternative -
(A) Pressure in the vessel after a long time becomes zero.

(B) Pressure in the vessel decreases to half of its initial value after a time $\dfrac{V_0}{\alpha RT_0} \ell n(2)$.

(C) At t = $\dfrac{V_0}{\alpha RT_0}$; Pressure in the vessel is $\dfrac{P_0}{e}$.

(D) At t = $\dfrac{V_0}{2\alpha RT_0}$; Pressure in the vessel is $\dfrac{P_0}{e}$.

[A,B,C]

Sol. $V_0(dP) = (dn) RT_0$ ....(i)

$\dfrac{dn}{dt} = -\alpha P$ ....(ii)

Q.19 The molar specific heat at constant volume of 3 moles of an ideal gas mixture is given by $C_V = aT$, where a is constant and T is the absolute temperature. Which of the following is correct -
(A) If the gas mixture undergoes adiabatic expansion, then change in its internal energy equals work done by it
(B) The specific heat of gas mixture at constant pressure is independent of number of moles
(C) Work done by gas mixture for all processes may depend upon number of moles
(D) The degree of freedom of mixture depends upon absolute temperature

Sol. **[B,C,D]**
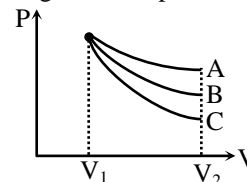$dU = -dW$
Specific heat is independent of number of moles
For constant volume process, $W = 0$

$C_V = \dfrac{1}{2} fR = aT$

Q.20 An ideal gas undergoes an expansion from a state with temperature T, and volume V_1 to V_2 through three different polytropic processes A, B and C as shown in the P–V diagram. If $|\Delta E_A|$, $|\Delta E_B|$ and $|\Delta E_C|$ be the magnitude of changes in internal energy along the three paths respectively -

(A) $|\Delta E_A| < |\Delta E_B| < |\Delta E_C|$ if temperature in every process decreases
(B) $|\Delta E_A| > |\Delta E_B| > |\Delta E_C|$ if temperature in every process decreases
(C) $|\Delta E_A| > |\Delta E_B| > |\Delta E_C|$ if temperature in every process increases
(D) $|\Delta E_B| < |\Delta E_A| < |\Delta E_C|$ if temperature in every process increases

Sol.[A,C] If $T_1 > T_2$

then $E_0 > E_f$

hence $(E_0 - E_A) < (E_0 - E_B) < E_0 - E_C$

$\Rightarrow |\Delta E_A| < |\Delta E_B| < |\Delta E_C|$

If $T_1 < T_2$ then $E_0 < E_f$ for all the processes

$|\Delta E_A| > |\Delta E_B| > |\Delta E_C|$

PHYSICS

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] $P = \tau W = \dfrac{d\theta}{dt} = (2m) s \dfrac{(\Delta T)}{\Delta t}$

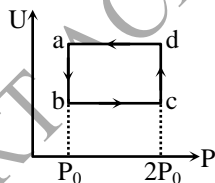**Q.2** Work done by gas in cyclic process in Joule is.
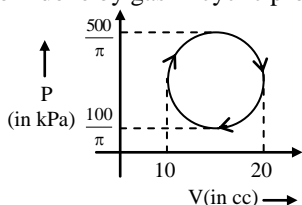
[0001]

Sol. Work done by gas

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

$= 1\ J$

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)

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

for process b → c, (T = constant)

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

for process c → d (P = constant)

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

for process d → a, (T = constant)

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

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

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

$\Delta Q = \Delta W$

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

∴ 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. $\Delta Q = \Delta U + W$
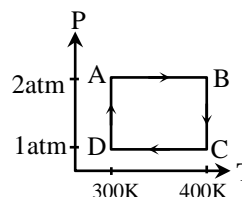
$10 = \Delta U + 5 \Rightarrow \Delta U = 5J$

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

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

$10 = C \times \dfrac{5}{C_V}$ [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
∵ 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]**

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

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

$(dT)_2 = 42\ K$

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]**

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

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

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 $x\cdot y \times 10^5$J, where x and y are single digit number find x. The gas is monotonic.

$P(10^5\ P_a)$

8

4

0.2 0.5

$V(m^3)$
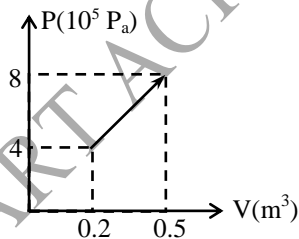
Sol.[6] $Q = \Delta U + W$

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

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

Q.10 One mole of ideal monoatomic gas is taken along a cyclic process as shown in the figure. Process $1 \rightarrow 2$ shown is $1/4^{th}$ part of a circle as shown by

dotted line process $2 \rightarrow 3$ is isochoric while $3 \rightarrow 1$ is isobaric. If efficiency of the cycle is n% where n is an integer. Find n.
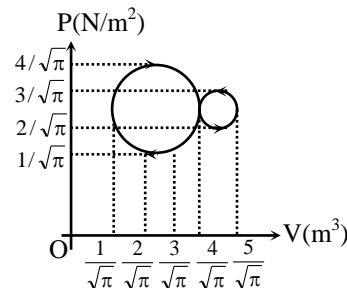

$2P_0$

P_0

$V_0\ \ 2V_0$
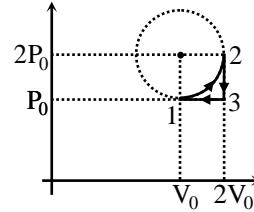
Sol. **[4]**

$W_{net} = (2P_0V_0) - (P_0V_0) - \dfrac{\pi P_0V_0}{4}$

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

Now,

$T_1 = \dfrac{P_0V_0}{R}$ $\Delta U_{1\rightarrow 2} = 1 \times \dfrac{3R}{2}[T_2 - T_1]$

$T_2 = \dfrac{4P_0V_0}{R}$ Thus, $\Delta U_{2\rightarrow 3} = 1 \times \dfrac{3R}{2}[T_3 - T_2]$

$T_3 = \dfrac{2P_0V_0}{R}$ $\Delta U_{3\rightarrow 1} = 1 \times \dfrac{3R}{2}[T_1 - T_3]$

$\Delta Q_{1\rightarrow 2} = (4.5)(P_0V_0) + (1.22)(P_0V_0) = (5.72)(P_0V_0)$

$\Delta Q_{3\rightarrow 2} = -3P_0V_0 + 0 = -3.22)(P_0V_0)$

$\Delta Q_{3\rightarrow 1} = -1.5(P_0V_0) - (P_0V_0) = -2.5(P_0V_0)$

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

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

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.

$P(N/m^2)$

$4/\sqrt{\pi}$

$3/\sqrt{\pi}$

$2/\sqrt{\pi}$

$1/\sqrt{\pi}$

O $\dfrac{1}{\sqrt{\pi}}$ $\dfrac{2}{\sqrt{\pi}}$ $\dfrac{3}{\sqrt{\pi}}$ $\dfrac{4}{\sqrt{\pi}}$ $\dfrac{5}{\sqrt{\pi}}$ $V(m^3)$

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

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

$= 2\ Joule.$

Q.12 A cylinder of ideal gas is closed by a 4 kg movable piston of area 30 cm². 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/m²

$g = 9.8$ m/sec²

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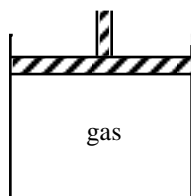
Sol.[7] During heating $P = \dfrac{4 \times 9.8}{30 \times 10^{-4}} + 1 \times 10^5$

$= 1.13 \times 10^5$ N/m²

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

During cooling $\Delta W = 0$

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

∴ Heat lost

$Q_2 = -Q_2' = \Delta U_1$

∴ $Q_1 - Q_2 = (\Delta U_1 + 68) - (\Delta U_1) = 68J \approx 70$ 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]** $\dfrac{P_2 V_2}{T_2} = 2\dfrac{P_1 V_1}{T_1}$

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

$V_2 = 2V_1$

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

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(m³)	0.1	0.2	0.4

The work done by the system is $n \times 10^3$J. Find n.

Sol. **[5]** $P_1 V_1^n = P_2 V_2^n = P_3 V_n^n$

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

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

$n = 2$

$W = \dfrac{P_1 V_1 - P_2 V_2}{n-1} = \dfrac{(100 \times 0.1 - 25 \times 0.2) \times 10^3}{2-1}$

$= 5 \times 10^3$ 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 $n \times 100$ 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 -
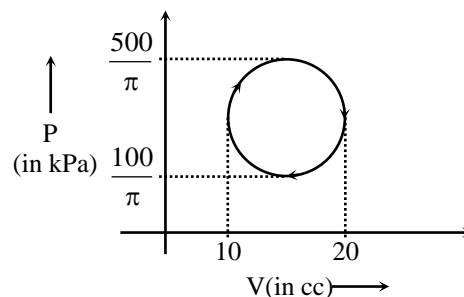
Sol. [5]

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]
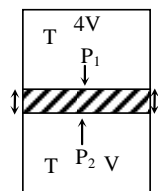
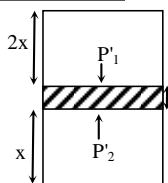

$\dfrac{PV}{RT}$ = constant and it is same for both part

$\therefore P_1 = P_2$

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

$P_1 A + mg = P_2 A \Rightarrow P_2 = P_1 + \dfrac{mg}{A}$

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

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

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

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

$P'_1 A + mg = P'_2 A \Rightarrow P'_2 = P'_1 + \dfrac{mg}{A}$

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

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

$T = \dfrac{3000}{4} \Rightarrow T = 750\,K$

Q.18 For a thermodynamic process, the pressure, volume and temperature are related as $P = \dfrac{\alpha T^2}{V}$ 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] $PV = \alpha T^2$

$PdV + VdP = 2\alpha T dT$

as pressure is constant

$dP = 0$

$PdV = 2\alpha T dT$

$W = \int PdV = \int\limits_{T_0}^{2T_0} 2\alpha T dT = 3\alpha\, T_0^2$

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.

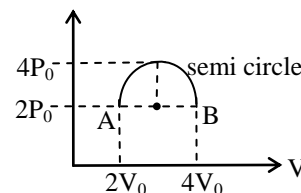**Sol.[1]** For cylinder A process is isobaric while for B, it is isochoric.

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

$Q_A = Q_B$ (given)

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

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

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 $K(\pi + 10)\,P_0 V_0$. Determine value of K.

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

$\qquad = (\pi + 4)\,P_0 V_0$

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

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

$\Delta Q = \Delta U + W = (\pi + 10)P_0 V_0$

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

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

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 –
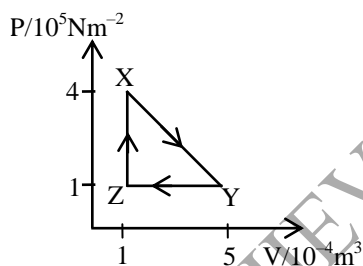
At which point is the gas coolest and hottest ?

| 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 $T = \dfrac{PV}{R}$

which is proportional to the product pV

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

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

At z, pV = (1×10^5) (1×10^{-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
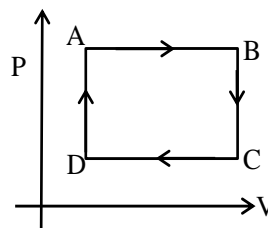
The above process in the P-T coordinates is given as
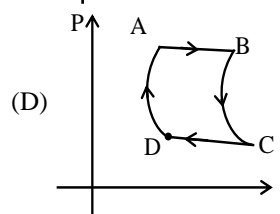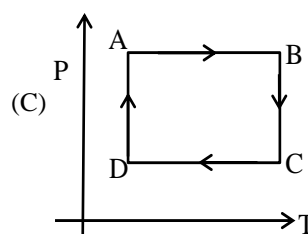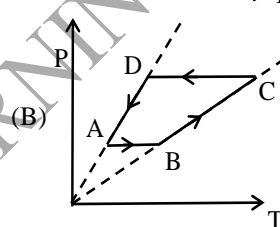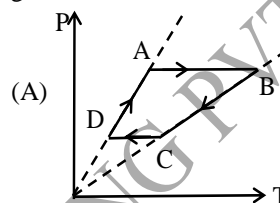
[A]

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) $\Delta U_{ab} > \Delta U_{ac} > \Delta U_{ad} > \Delta U_{ae}$
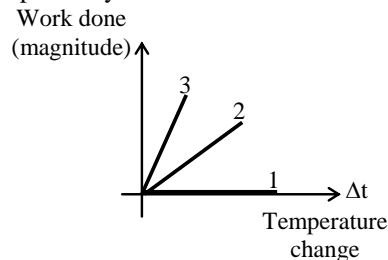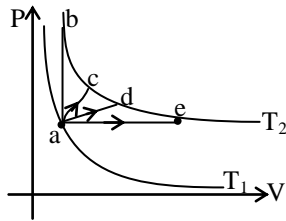
(B) $\Delta U_{ab} = \Delta U_{ac} > \Delta U_{ad} > \Delta U_{ae}$

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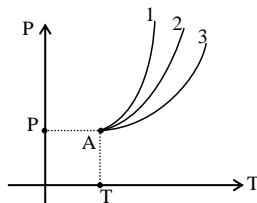
(A) $\dfrac{R}{1-\gamma}$ (B) $\dfrac{R}{\gamma-1}$

(C) R   (D) $\dfrac{R}{2}$ **[A]**

Q. 7 The molar heat capacity for a process is $C = \dfrac{R}{\gamma-1} + \dfrac{\alpha}{T}$, 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 ($\gamma = 4/3$) gases. The slopes for curves 1, 2, 3 respectively at point A are –

(A) $2.5\dfrac{P}{T}, 3.5\dfrac{P}{T}, 4.5\dfrac{P}{T}$ (B) $2.5\dfrac{P}{T}, 3\dfrac{P}{T}, 4\dfrac{P}{T}$

(C) $2.5\dfrac{P}{T}, 3.5\dfrac{P}{T}, 4\dfrac{P}{T}$ (D) $2\dfrac{P}{T}, 3\dfrac{P}{T}, 4\dfrac{P}{T}$

[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 m². The pressure of gas in final situation is –
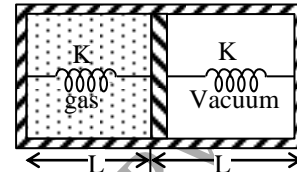
(A) 50 N/m²   (B) 100 N/m²

(C) 200 N/m²   (D) 400 N/m²   **[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) $\dfrac{7}{5P}$ (B) $\dfrac{5}{7P}$

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

Sol.

$dQ = -dU$

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

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

$T^5 V = $ const.

$V = \dfrac{const}{T^5}$

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

$PV = nRT$

$P/n = RT/V$

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

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

$\gamma = 7/5$

adiabatic compressibility

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

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

$Q = \Delta U$

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

$U_{mix} = U_1 + U_2$

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

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

$V'_{rms} = 2V_{rms} \Rightarrow T' = 4T$
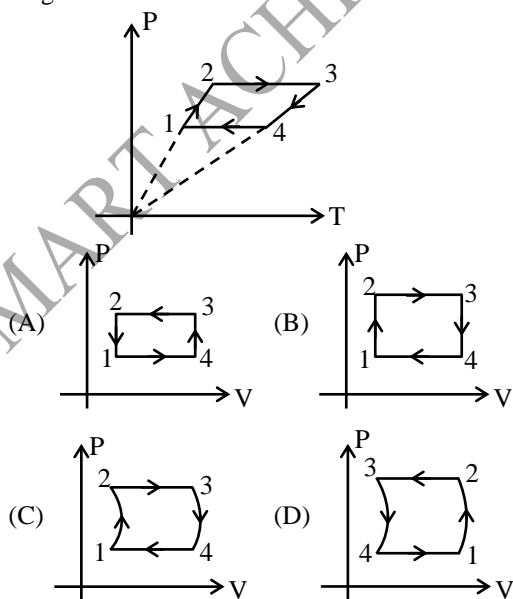
$n_1 = \dfrac{8}{4} = 2$; $n_2 = \dfrac{14}{28} = 1/2$

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

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

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

$\dfrac{17}{4} \times R \times 100 = 3825\ R$

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

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]**

$\Delta U = nC_v \Delta T$

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

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

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

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

$= \dfrac{15 \times 10^3 \times 0.08 \times 5}{39} \times (-70)$
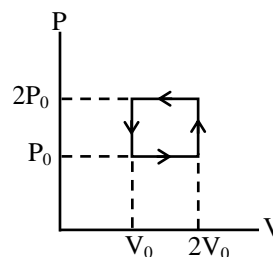
$= -\dfrac{0.40}{39} \times 15 \times 10^3 \times 70$

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

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

$\Delta U = -11000$ 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
$W = -P_0 V_0$
$= -8 \times (10^5 \times 1.01) \times 7 \times 10^{-3}$
$W = -56 \times 1.01 \times 10^2$ 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 –
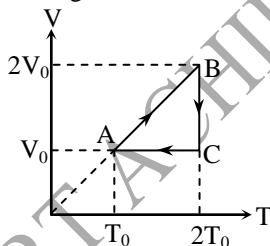
    (A) $\dfrac{5}{2\ln 2}$ (B) $\dfrac{5}{3}$

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

Sol. **[C]**

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

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

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

Q.17 An ideal gas is taken through the cycle $A \to B \to C \to A$, 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 $C \to A$ is –
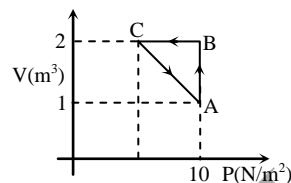
    (A) –5 J   (B) – 10 J
    (C) – 15 J   (D) – 20 J

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)
$\therefore \quad \Delta Q = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$
$\therefore \quad \Delta W_{CA} = \Delta Q - \Delta W_{AB} - \Delta W_{BC} = 5 - 10 - 0$
        $= -5$ 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 $\dfrac{2}{3}\alpha$ nRT

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

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

    (D) The change in internal energy for a temperature change T is $\dfrac{5}{2}\alpha$nRT

Sol. **[B]** Internal energy change is
    $\Delta U = n\,C_V\,\Delta T$
    $= n\dfrac{5}{2}R(T-0)$
    $= \dfrac{5}{2}$ 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 –
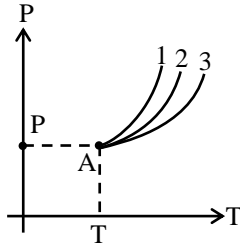
(A) $2.5 \dfrac{P}{T}$, $3.5 \dfrac{P}{T}$, $4.5 \dfrac{P}{T}$

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

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

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

Sol. **[D]**

For adiabatic process :

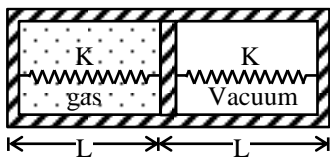Slope : $\dfrac{dP}{dT} = \left(\dfrac{\gamma}{\gamma-1}\right) \dfrac{P}{T}$

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

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

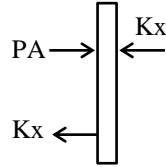$\gamma = \dfrac{7}{5} \Big| \dfrac{dP}{dT} = \left(\dfrac{7/5}{2/5}\right) \dfrac{P}{T} = 3.5 \dfrac{P}{T}$

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

Q.20 Area of piston is 1 m². When heat is supplied to the gas it expands and displaces piston by $\dfrac{L}{2}$ 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/m²   (B) 100 N/m²

(C) 200 N/m²   (D) 400 N/m²

Sol. **[B]**

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

$= \dfrac{2 \times 100}{1} \times \dfrac{1}{2}$

$= 100 \text{ N/m}^2$

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

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

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

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

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

Sol. **[B]**

$U = U_0 V \Rightarrow nC_V T = U_0 V \Rightarrow T \propto V$ isobaric process

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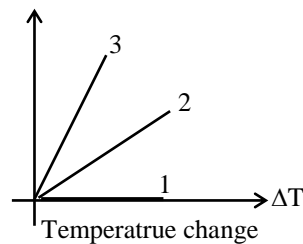
$\dfrac{dV}{dT} = $ constant

$\dfrac{P}{n} = \dfrac{nRT}{V} = \dfrac{nRT}{\text{constant}T}$

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

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

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

work done (magnitude)

(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 : $W = P\Delta V = nR\Delta T$

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

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

$0 < \gamma - 1 < 1$

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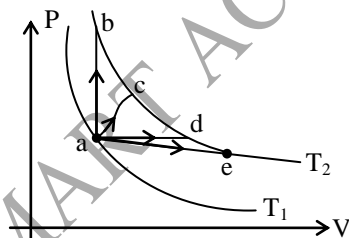
(A) $\dfrac{13R}{6}$ (B) $\dfrac{11R}{6}$

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

Sol.   **[B]**

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

$\dfrac{3R + \dfrac{5}{2}R}{3}$

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

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) $\dfrac{R}{1-\gamma}$ (B) $\dfrac{R}{\gamma - 1}$

(C) R   (D) R/2

Sol.   **[A]**

$dQ = -dU$

$nCdT = -nC_V dT$

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

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

Q.26 The molar heat capacity for a process is :

$C = \dfrac{R}{\gamma - 1} + \dfrac{\alpha}{T}$, 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]**

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

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

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

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

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

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

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

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 –
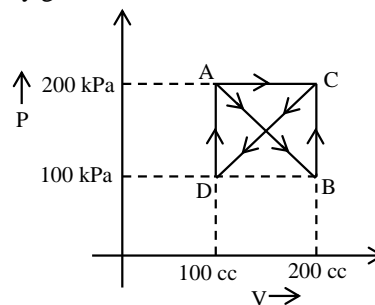
(A) 5 kJ   (B) 2.5 kJ
(C) – 5 kJ   (D) 7.5 kJ   **[B]**

Sol.
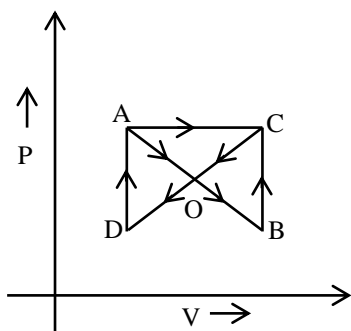
Work done = area (AOD) + area (AOC)

$\qquad$ – area (BOC)

$\qquad$ = area (AOC)

$\qquad$ = 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

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

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

$\quad$ From eq. (i) & (ii)

$\quad \dfrac{\gamma}{\gamma-1} = 3 \Rightarrow \gamma = 3\gamma - 3$

$\qquad\qquad\quad \gamma = 3/2$

Q.41 A polyatomic gas ($\gamma = \dfrac{4}{3}$) is compressed to $1/8^{th}$ 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.

$\quad P_0 V^{4/3} = P'\left(\dfrac{V}{8}\right)^{4/3}$

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

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

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

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

Sol. For adiabatic process

$\quad \dfrac{\Delta P}{\Delta V} = -\dfrac{\gamma P}{V}$

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

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

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

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) $W_2 = \dfrac{W_1}{\ln(2)}$

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

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ **[A]**

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

$\quad = nRT(2-1) = nRT$

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

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. $\Delta Q = nC_P \Delta T = \dfrac{7}{2} nR\Delta T$

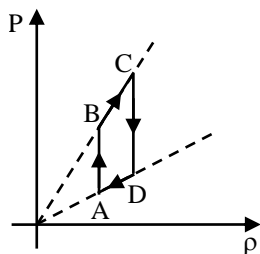$\quad \left(C_P = \dfrac{7}{2}R\right)$

$\quad \Delta U = nC_V \Delta T = \dfrac{5}{2} nR\Delta T$

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

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

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

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

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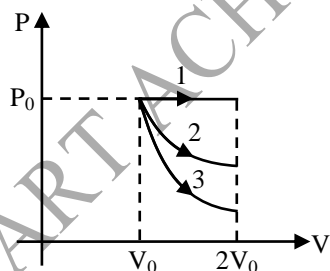
(A) $\Delta U_1 > \Delta U_2 > \Delta U_3$

(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 $\rho = \dfrac{m}{V}$

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

∴ Eq. (1) can be written as

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

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

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) $-\dfrac{2P_0V_0}{5R}$ (B) $\dfrac{11P_0V_0}{10R}$

(C) $-\dfrac{5P_0V_0}{4R}$ (D) P_0V_0 **[B]**

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

∴ $T_i = \dfrac{PV}{nR} = \dfrac{\left(\dfrac{P_0}{2}\right)(V_0)}{R} = \dfrac{P_0V_0}{2R}$ (n = 1)

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

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

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

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 $0 = dU + PdV$

From the given equation

$dU = 3 (PdV + VdP)$

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

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

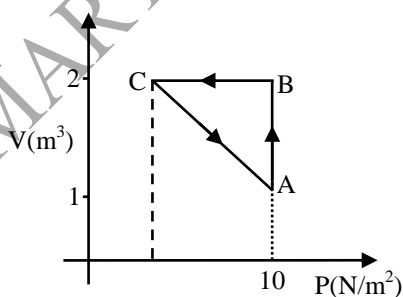or $4\left(\dfrac{dV}{V}\right) = -3\left(\dfrac{dP}{p}\right)$

On integrating, we get

$ln(V^4) + ln(P^3) = $ constant

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

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

i.e., gas is polyatomic.

Q.50 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   **[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

PHYSICS

Q.1 A certain amount of gas initially occupying a volume V_0 at a pressure P_0 and a temperature T_0 expands first at constant pressure and then at constant temperature to a volume V_1.

In which of these two cases will the gas do more work?

Sol. For all volumes from V_0 to V_1 the gas pressure in the constant-pressure process will be larger than in the constant-temperature one **(Fig.)**. Accordingly, the work done by the gas will also be larger in the constant-temperature process (see the solution to **Q. 8**).
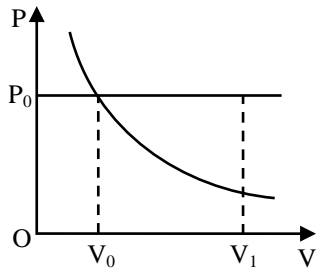
During expansion at constant pressure. **Ans.**

Q.2 A cylinder filled with gas is placed in a heat-proof jacket.

How will the temperature of the gas change if the volume of the cylinder is gradually increased?

Sol. The temperature of the gas will decrease because some of the internal energy of the gas is converted into the mechanical work during expansion.

Q.3 One kg of steam with a quality of 20 percent is heated at a constant pressure of 200 kPa until the temperature reaches 400ºC. Calculate the work done by the steam.

Sol. The work is given by
$W = \int PdV = P(V_2 - V_1) = mP(v_2 - v_1)$

To evaluate the work we must determine v_1 and v_2. Using Table C-2 we find
$v_1 = v_f + x(v_g - v_f) = 0.001061 + (0.2)(0.8857 - 0.001061) = 0.1780 \text{ m}^3/\text{kg}$
We locate state 2 at $T_2 = 400$ºC and $P_2 = 0.2$ MPa:
$v_2 = 1.549 \text{ m}^3/\text{kg}$
The work is then
$W = (1)(200)(1.549 - 0.1780) = \textbf{274.2 kJ}$

Ans.

Note : With the pressure having units of kPa, the result is in kJ.

Q.4 A 110-mm-diameter cylinder contains 100 cm^3 of water at 60ºC. A 50-kg piston sits on top of the water. If heat is added until the temperature is 200ºC, find the work done.

Sol. The pressure in the cylinder is due to the weight of the piston and remains constant. Assuming a frictionless seal (this is always done unless information is given to the contrary), a force balance provides
$mg = PA - P_{atm}A$

$(50)(9.81) = (P - 100000) \dfrac{\pi(0.110)^2}{4}$

$\therefore P = 151600 \text{ Pa}$
The atmospheric pressure is included so that absolute pressure results. The volume at the initial state 1 is given as
$V_1 = 100 \times 10^{-6} = 10^{-4} \text{ m}^3$
Using v_1 at 60ºC, the mass is calculated to be

$M = \dfrac{V_1}{v_1} = \dfrac{10^{-4}}{0.001017} = 0.09833 \text{ kg}$

At state 2 the temperature is 200ºC and the pressure is 0.15 MPa (this pressure is within 1 percent of the pressure of 0.1516 MPa, so it is acceptable). The volume is then
$V_2 = mv_2 = (0.09833)(1.444) = 0.1420 \text{ m}^3$
Finally, the work is calculated to be
$W = P(V_2 - V_1) = 151(600) (0.1420 - 0.0001) = 21500 \text{ J}$ or **21.5 kJ** **Ans.**

Q.5 Energy is added to a piston-cylinder arrangement, and the piston is withdrawn in such a way that the quantity PV remains constant. The initial pressure and volume are 200 kPa and 2 m^3, respectively. If the final pressure is 100 kPa, calculate the work done by the gas on the piston.

Sol. $W_{1-2} = \int_2^{V_2} P \, dV = \int_2^{V_2} \dfrac{C}{V} \, dV$

where we have used PV = C. To calculate the work we must find C and V_2. The constant C is found from
$C = P_1V_1 = (200)(2) = 400 \text{ kJ}$
To find V_2 we use $P_2V_2 = P_1V_1$, which is, of course, the equation that would result from an

isothermal process (constant temperature) involving an ideal gas. This can be written as

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{(220)(20)}{100} = 4 m^3$$

Finally,

$$W_{1-2} = \int_2^{4} \frac{400}{V} dV = 400 \ln \frac{4}{2} = 277 \text{ kJ}$$

This is positive, since work is done during the expansion process by the system (the gas contained in the cylinder).

Q.6 Determine the horsepower required to overcome the wind drag on a streamlined car traveling 90 km/h if the drag coefficient C_D is 0.2. The drag force is given by $F_D = \frac{1}{2}\rho V^2 A C_D$, where A is the projected area of the car and V is the velocity. The density ρ of air is 1.23 kg/m³. Use $A = 2.3$ m².

Sol. To find the drag force on a car we must express the velocity in m/s; $V = (90)(1000/3600) = 25$ m/s. The drag force is then

$F_D = \frac{1}{2}\rho V^2 A C_D$

$= (\frac{1}{2})(1.23)(25^2)(2.3)(0.2) = 177$ N

To move this drag force at 25 m/s the engine must do work at the rate

$W = F_D V = (177)(25) = 4425$ W

The horsepower is then

$$H_p = \frac{4425}{746 \text{ W/hp}} = 5.93 \text{ hp} \quad \textbf{Ans.}$$

Q.7 A 100-kg mass drops 3 m, resulting in an increased volume in the cylinder of 0.002 m³ **(Fig.)**. The weight and the piston maintain a constant gage pressure of 100 kPa. Determine the net work done by the gas on the surroundings. Neglect all friction.
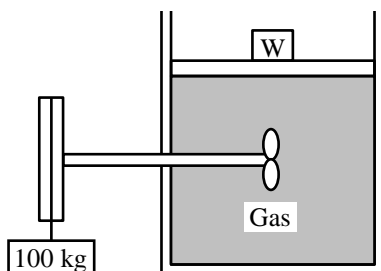
Sol. The paddle wheel does work on the system, the gas, due to the 100-kg mass dropping 3 m. That work is negative and is

$W = -(F)(d) = -(100)(9.81)(3) = -2940$ J

The work done by the system on this frictionless piston is positive since the system is doing the work. It is

$W = (PA)(h) = PV = (200000)(0.002) = 400$ J

where absolute pressure has been used. The net work done is thus

$W_{net} = -2940 + 400 = -2540$ J. **Ans.**

Q.8 The air in a circular cylinder **(Fig.)** is heated until the spring is compress 50 mm. Find the work done by the air on the frictionless piston. The spring is initially unstretched, as shown.
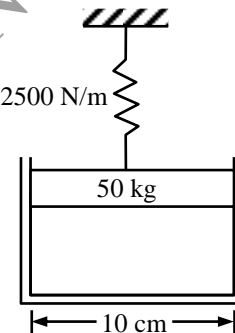
Sol. The pressure in the cylinder is initially found from a force balance:

$P_1 A_1 = P_{atm} A + W$ $\qquad P_1 \frac{\pi(0.1)^2}{4} =$

$(100000) \frac{\pi(0.1)^2}{4} + (50)(9.81)$

$\therefore P_1 = 162500$ Pa

To raise to the piston a distance of 50 mm, without the spring, the pressure would be constant and the work required would be force times distance:

$$W = PA \times d = (162500) \frac{\pi(0.1)^2}{4} (0.05) = 63.81 \text{ J}$$

The work required to compress the spring is

$W = \frac{1}{2}K(x_2^2 - x_1^2) = (\frac{1}{2})(2500)(0.05^2) = 3.125$ J

The total work is then found by summing the above two values:

$W_{total} = 63.81 + 31.25 = 66.94$ J. **Ans.**

Q.9 A paddle wheel adds work to a rigid container by rotations caused by dropping a 50-kg weight a distance of 2 m from a pulley. How much heat must be transferred to result in an equivalent effect?

Sol. For this non-quasi equilibrium process the work is given by W = (mg)(d) = (50)(9.8)(2) = 980 J. The heat Q that must be transferred equals the work, 980 J.

Q.10 Nitrogen at 100°C and 600 kPa expands in such a way that it can be approximated by a polytropic process with n = 1.2. Calculate the work and the heat transfer if the final pressure is 100 kPa.

Sol. The final temperature is found to be

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{(n-1)/n} = (373)\left(\frac{100}{600}\right)^{(1.2-1)/1.2} = $$

276.7 K

The specific volumes are

$$v_1 = \frac{RT}{P_1} = \frac{(0.297)(373)}{600} = \quad 0.1846 \quad m^3/kg$$

$$v_2 = \frac{RT_2}{P_2} = \frac{(0.297)(276.7)}{100} = 0.822 \ m^3/kg$$

The work is then

$$w = \int P dv = P_1 v_1^n \int v^{-n} dv = (600)(0.1846)^{1.2}$$

$$\left(\frac{1}{-0.2}\right)(0.822^{-0.2} - 0.1846^{-0.2}) = 143 \ kJ/k$$

The first law provides us with the heat transfer:

q − w = Δu = c_v(T_2 − T_1) q − 143 = (0.745)(276.7 − 373) ∴ q = 71.3 kJ/kg

Q.11 Six g of air is contained in the cylinder shown in **Fig.** The air is heated until the piston raises 50 mm. The spring just touches the piston initially. Calculate **(a)** the temperature when the piston leaves the stops and **(b)** the work done by the air on the piston.
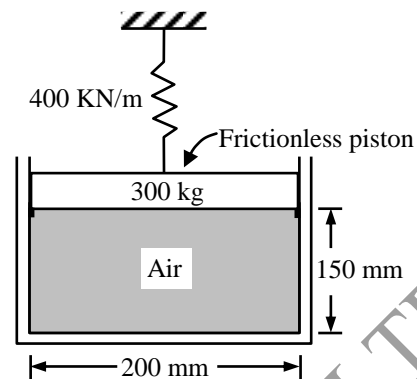
Sol. **(a)** The pressure in the air when the piston just raises from the stops is found by balancing the forces on the piston:

$$PA = P_{atm} A + W \ \frac{P\pi(0.2)^2}{4} = $$

$$(100000)\frac{\pi(0.2)^2}{4} + (300)(9.81)$$

∴ P = 193700 Pa or 193.7 kPa

The temperature is found from the ideal-gas law:

$$T = \frac{PV}{mR} = \frac{(193.7)(0.15)(\pi)(0.2)^2/4}{(0.006)(0.287)} = 530 \ K$$

Ans.

(b) The work done by the air is considered to be composed of two parts: the raise the piston and the work to compress the spring. The work required to raise the piston a distance of 0.05 m is
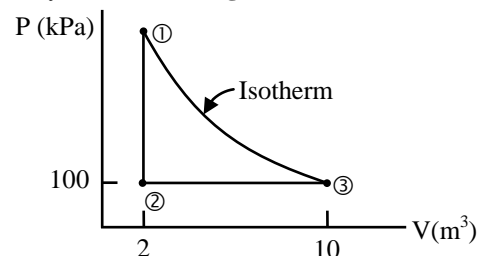
$$W = (F)(d) = (P)(A)(d) = (193.7)\frac{\pi(0.2)^2}{4}(0.05)$$

= 0.304 kJ

The work required to compress the spring is W = ½ Kx² = 0.5 kJ. The total work required by the air to raise the piston is

W = 0.304 + 0.5 = 0.804 kJ. **Ans.**

Q.12 Two kg of air experiences the three-process cycle shown in **Fig.** Calculate the net work.

Sol. The work for the constant-volume from state 1 to state 2 is zero since $dV = 0$. For the constant-pressure process the work is

$W_{2\text{-}3} = \int PdV = P(V_3 - V_2) = (100)(10 - 2) = 800$ kJ

The work needed for the isothermal process is

$$W_{3-1} \int PdV = \int \frac{mRT}{V} dV = mRT \int_{V_3}^{V_1} \frac{dV}{V} = mRT \ln \frac{V_1}{V_3}$$

To find W_{3-1} we need the temperature. It is found from state 3 to be

$$T_3 = \frac{V_1 V_3}{mR} = \frac{(100)(10)}{(2)(0.287)} = 1742 \text{ °R}$$

Thus, the work for the constant-temperature process is

$$W_{3-1} = (2)(0.287)(1742) \ln \frac{2}{10} = -1609 \text{ kJ}$$

Finally, the net work is

$W_{net} = \cancel{W_{1-2}}^{0} + W_{2-3} + W_{3-1} = 800 - 1609 = -809$ kJ **Ans.**

The negative sign means that there must be a net input of work to complete the cycle in the order shown above.

Q.13 A paddle wheel (**Fig.**) requires a torque of 20 ft-lbf to rotate it at 100 rpm. If it rotates for 20 s, calculate the net work done by the air if the frictionless piston raises 2 ft during this time.
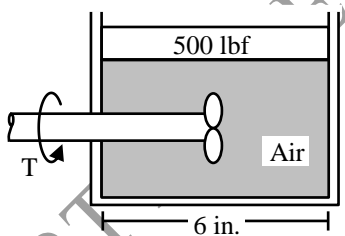
Sol. The work input by the paddle wheel is

$W = - T\omega \Delta t = (-20 \text{ ft-lbf}) \left[\frac{(100)(2\pi)}{60} \text{rad/sec} \right] (20 \text{ s}) = -4190$ ft-lbf

The negative sign accounts for work being done on the system, the air. The work needed to raise the piston requires that the pressure be known. It is found as follows:

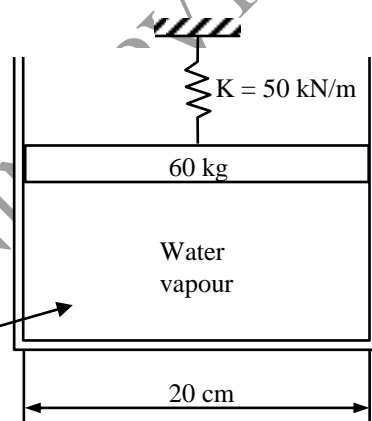$PA = P_{atm}A + W$ $P \frac{\pi(6)^2}{4} = (14.7) \frac{\pi(6)^2}{4} + 500$

$\therefore P = 32.4$ psia

The work done by the air to raise the piston is then

$W = (F)(d) = (P)(A)(d) = (32.4) \frac{\pi(6)^2}{4} (2) = 1830$ ft-lbf

and the net work is $W_{net} = 1830 - 4190 = -2360$ ft-lbf. **Ans.**

Q.14 A piston moves upward a distance of 5 cm while 200 J of heat is added (**Fig.**). Calculate the change in internal energy of the vapour if the spring is originally unstretched.

Sol. The work needed to raise the weight and compress the spring is

$$W = (mg)(h) + \frac{1}{2} Kx^2 + (P_{atm})(A)(h)$$

$$= (60)(9.81)(0.05) + \left(\frac{1}{2} \right) (50000)(0.5)^2 + (100000) \left[\frac{\pi(0.2)^2}{4} \right] (0.05) = 250 \text{ J}$$

The first law for a process without kinetic or potential energy changes is

$Q - W = \Delta U$

Thus, we have $\Delta U = 200 - 250 = -50$ J.

Ans.

Q.15 Gaseous hydrogen contained initially under standard conditions in a sealed vessel of volume $V = 5$ litre was cooled by $\Delta T = 55$ K. Find how much the internal energy of the gas will change and what amount of heat will be lost by the gas.

**Ans.** $\Delta U = -0.25$ KJ, $\Delta Q = 0.25$ KJ

Q.16 An ideal gas is originally confined to a volume V_1 in an insulated container of volume $V_1 + V_2$. The remainder of the container is evacuated. The partition is then removed and the gas expands to fill the entire container. If the initial temperature of the gas was T, what is the final temperature? Justify your answer.

insulated container

V_1	V_2
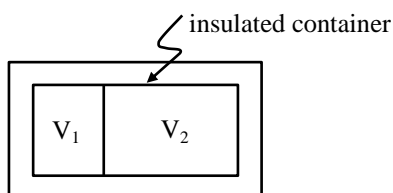
Sol. This is a process of adiabatic free expansion of an ideal gas. The internal energy does not change; thus the temperature does not change, that is, the final temperature is still T.

Q.17 An insulated chamber is divided into two halves of volumes. The left half contains an ideal gas at temperature T_0 and the right half is evacuated. A small hole is opened between the two halves, allowing the gas to flow through, and the system comes to equilibrium. No heat is exchanged with the walls, Find the final temperature of the system.

Sol. After a hole has been opened, the gas flows continuously to the right side and reaches equilibrium finally. During the process, internal energy of the system E is unchanged. Since E depends on the temperature T only for an ideal gas, the equilibrium temperature is still T_0.
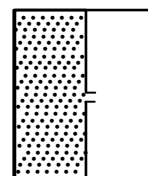
Q.18 The figure below shows an apparatus for the determination of C_p/C_v for a gas, according to the method of Clement and Desormes. A bottle G, of reasonable capacity (say a few litres), is fitted with a tap H, and a manometer M. The difference in pressure between the inside and the outside can thus be determined by observation of the difference **h** in heights of the two columns in the manometer. Thue bottle is filled with the gas to be investizated, at a very slight excess pressure over the outside atmospheric pressure. The bottle is left in peace (with the tap closed) until the temperature of the gas in the bottle is the same as the same the outside temperature in the room. Let the reading of the manometer be h_1. The tap H is then opened for a very short time, just sufficient for the internal pressure to become equal to the atmospheric pressure (in which case the manometer reads h = 0). With the tap closed the bottle is left in peace for a while, until the inside temperature has become equal to the outside temperature. Let the final reading of the manometer be **h**. From the values of h_i and h_f it is possible to find C_p/C_v.

(a) Derive an expression for C_p/C_v in terms of h_i and h_f in the above experiment.

(b) Suppose that the gas in question is oxygen. What is your theoretical prediction for C_p/C_v at 20ºC, within the framework of statistical mechanics?
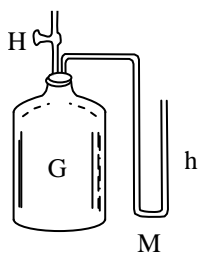
Sol. **(a)** The equation of state of ideal gas is $pV = nkT$. Since the initial and final T, V of the gas in the bottle are the same, we have $p_f/p_i = n_f/n_i$.

Meanwhile, $n_f/n_i = V/V'$, where V' is the volume when the initial gas in the bottle expands adiabatically to pressure p_0. Therefore

$$\frac{V}{V'} = \left(\frac{p_0}{p_i}\right)^{\frac{1}{7}}. \qquad \frac{p_f}{p_i} = \left(\frac{p_0}{p_i}\right)^{\frac{1}{7}},$$

$$\gamma = \frac{\ln \dfrac{p_i}{p_0}}{\ln \dfrac{p_i}{p_f}} = \frac{\ln\left(1 + \dfrac{h_i}{h_0}\right)}{\ln\left(1 + \dfrac{h_i}{h_0}\right) - \ln\left(1 + \dfrac{h_f}{h_0}\right)}.$$

Since $h_i/h_0 < 1$ and $h_f/h_0 < 1$, we have $\gamma = h_i/(h_i - h_f)$.

(b) Oxygen consists of diatomic molecules. When $t = 20ºC$, only the translational and rotational motions of the molecules contribute to the specific heat. Therefore

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

Q.19 10 litres of gas at atmospheric pressure is compressed isothermally to a volume of 1 litre and then allowed to expand adiabatically to 10 lites.

(a) Sketch the process on a pV diagram for a monatomic gas.

(b) Make a similar sketch for a diatomic gas.

(c) Is a net work done on or by the system?

(d) Is it greater or less for the diatomic gas?

Sol. We are given that $V_A = 10l$, $V_B = 1l$, $V_C = 10l$ and $p_A = 1$ atm.

$A \to B$ is an isothermal process, thus

$pV = $ const. or $p_A V_A = p_B V_B$,

hence

$$p_B = \frac{V_A}{V_B} p_A = 10 \text{ atm.}$$

(The curve AB of the two kinds of gas are the same).

$B \to C$ is an adiabatic process, thus

$pV^\gamma = $ const, or $p_B V_B^\gamma = p_C V_C^\gamma$, hence

$$p_C = \left(\frac{V_B}{V_C}\right)^\gamma p_B = 10^{1-\gamma} \text{ atm.}$$

(a) For the monatomic gas, we have

$\gamma = 5/3, p_C = 10^{-2/3} = 0.215$ atm.

(b) For the diatomic gas, we have

$\gamma = 7/5, p_C = 10^{-2/5} = 0.398$ atm.

The two processes are shown in the figures (The cureve BC of monatomic gas (a) is lower than that of the diatomic gas (b)).

(c) In each case, as the curve AB for compression is higher than the curve BC for expansion, net work is done on the system. As p_C (monatomic gas) $< p_C$ (diatomic gas) the work on the monatomic gas is greater than that on the diatomic gas.
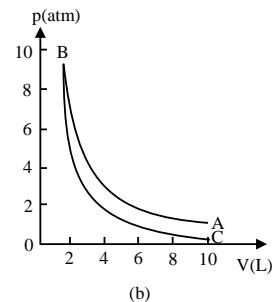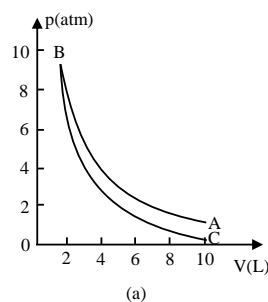
Q.20 An ideal gas is contained in a large jar of volume V_0. Fitted to the jar is a glass tube of cross-sectional area A in which a metal ball of

mass M fits snugly. The equilibrium pressure in the jar is slightly higher than atmospheric pressure p_0 because of the weight of the ball. If the ball is displaced slightly from equilibrium it will execute simple harmonic motion (neglecting friction). If the states of the gas represent a quasistatic adiabatic process and γ is the ratio of specific heats, find a relation between the oscillation frequency f and the variables of the problem.
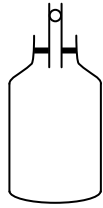
Sol. Assume the pressure in the jar is p. As the process is adiabatic, we have

$$pV^\gamma = \text{const},$$

giving

$$\frac{dp}{p} + \gamma \frac{\partial V}{V} = 0.$$

This can be written as $F = Adp = -kx$, where F is the force on the ball, $x = dV/A$ and $k = \gamma A^2 p/V$. Noting that $p = p_0 + mg/A$, we obtain

$$F = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{\gamma A^2\left(p_0 + \frac{mg}{A}\right)}{Vm}} \ .$$