CBSE Test Paper 04
Chapter 12 Thermodynamics

1. What amount of heat must be supplied to 2.0 $\times$ 10^{-2} kg of nitrogen (at room temperature) to raise its temperature by 45 $^\circ$C at constant pressure? (Molecular mass of N_2 = 28; R = 8.3 J mol^{-1} K^{-1}.) **1**

   a. 904 J
   b. 974 J
   c. 954 J
   d. 934 J

2. Two cylinders A and B of equal capacity are connected to each other via a stopcock. A contains a gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. Do the intermediate states of the system (before settling to the final equilibrium state) lie on its P-V-T surface? **1**

   a. yes
   b. no for points on the left
   c. No
   d. yes for points on the left

3. The spontaneous processes of nature are **1**

   a. irreversible
   b. static
   c. reversible
   d. dynamic

4. The efficiency (η) of a heat engine is defined by (W is the output and Q_1 the heat input) **1**

   a. η = $\frac{Q_1}{W}$
   b. η = $\frac{2W}{Q_1}$

c. $\eta = \frac{W}{2Q_1}$
d. $\eta = \frac{W}{Q_1}$

5. A 1.0-mol sample of an ideal gas is kept at 0.0°C during an expansion from 3.0 L to 10.0 L. If the gas is returned to the original volume by means of an isobaric process, how much work is done by the gas? **1**

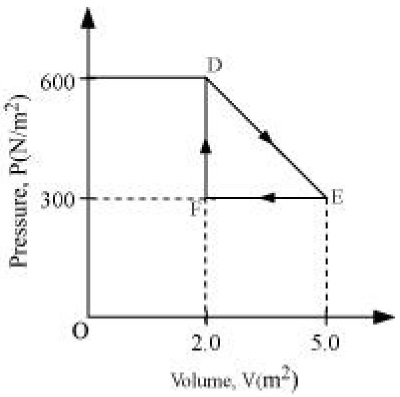
   a. -1.6 $\times\ 10^3$ J
   b. -1.4 $\times\ 10^3$
   c. -1.3 $\times\ 10^3$
   d. -1.5 $\times\ 10^3$

6. Write conditions for an isothermal process. **1**

7. On a winter night, you feel warmer when clouds cover the sky than when sky is clear. Why? **1**

8. Under what condition, an ideal Carnot engine has 100% efficiency? **1**

9. A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in figure. **2**



   Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F.

10. If a body is heated from 27^0 C to 927^0 C then what will be the ratio of energies of radiation emitted? **2**

11. Find molar specific heat for the process $p = \frac{a}{T}$ for a monoatomic gas. **2**

12. A brass boiler has a base area of 0.15 m^2 and thickness 1.0 cm. It boils water at the

rate of 6kg/min when placed on a gas stove, Estimate the temperature of the part of flame in contact with the boiler. Thermal conductivity of brass = 109J/s/m/^{0}C, heat of vaporization of water = 2256 J/g? **3**

13. Temperatures of the hot and cold reservoirs of a Carnot engine is raised by equal amounts. How the efficiency of the Carnot engine affected? **3**

14. A gaseous mixture enclosed in a vessel consists of 1 g mole of a gas A$\left(\gamma = \frac{5}{3}\right)$ and some amount of gas B$\left(\gamma = \frac{7}{5}\right)$ at a temperature T. The gases A and B do not react with each other and are assumed to be ideal.
Find the number of gram moles of the gas B, if γ for the gaseous mixture is $\left(\frac{19}{13}\right)$. **3**

15. Consider that an ideal gas (*n* moles) is expanding in a process given by *P* = f (V), which passes through a point (V_0, P_0). Show that the gas is absorbing heat at (P_0, V_0) if the slope of the curve P = f (V) is larger than the slope of the adiabat passing through (P_0, V_0). **5**

Answer

1. d. 934 J

   Explanation: $Q = nC_v\Delta T = \frac{2\times10^{-2}\times10^{-3}}{28} \times \frac{7}{2} \times 8.3 \times 45$ = 934J

   $n = \frac{\text{wtingm}}{\text{Molecularwt}}$

   $C_v = \frac{7}{2}R\ for\ Diatomic\ Gas$

2. c. No

   Explanation: Pressure and volume will be changed.

3. a. irreversible

   Explanation: Spontaneous processes are irreversible because they can be reversed only by taking a different path to get back to their original state. A reversible process can take the same path to return to its original state.

4. d. η = $\frac{W}{Q_1}$

   Explanation: $\eta = \frac{\text{WorkDone}}{\text{HeatInput}} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

5. a. -1.6 $\times$ 10^3 J

   Explanation: W = nR (T_f - T_i) $W = nR\left(T_f - T_i\right)$

   $V \propto T$

   $\frac{10}{273} = \frac{3}{T_f}$

   T_f = 81.9 K

   T_i = 273 K

   $W = 1 \times 8.31 \times (81.9 - 273) = -1.6 \times 10^3 J$

6. The conditions for an isothermal process are

   i. The process should be quasi-static.
   ii. The walls should be diathermic.

7. We know that earth absorbs heat in day and radiates at night. When sky is covered,

with clouds, the heat radiated by earth is reflected back and earth becomes warmer. But if sky is clear the heat radiated by earth escapes into space.

8. As we know that efficiency of a Carnot engine is given by:
$\eta = \left(1 - \frac{T_2}{T_1}\right)$
where, T_1 = temperature of sink source and T_2 = temperature of sink.

So for η =1 or 100%,
T_2 = 0 K
or in other words we can say that heat is rejected into a sink at 0 K temperature.

9. Total work done by the gas from D to E to F = Area of ΔDEF
Area of $\Delta DEF = \frac{1}{2} DE \times EF$
Where,
DF = Change in pressure
$= 600 N/m^2 - 300 N/m^2$
= 300 N/m^2
FE = Change in volume
= 5.0 m^3 - 2.0 m^3 = 3.0 m^3
Area of $\Delta DEF = \frac{1}{2} \times 300 \times 3$ = 450 J
Therefore, the total work done by the gas from D to E to F is 450 J.

10. Since, By Stefan's law: $\rightarrow$
E = Energy radiated
T = Temperature.
E_1, T_1 $\Rightarrow$ Initial energy and temperature
E_2, T_2 $\Rightarrow$ Final energy and temperature.
T_1 = 27^0C = 27 + 273 = 300K
T_2 = 927^0C = 927 + 273K = 1200K.
E = constant T^4
So, E_1 = constant T_1^4
$\frac{E_1}{T_1^4} = constant$ ...(i)

Also, $\frac{E_2}{T_2^4} = constant$ ...(ii)

Equating equation (i) & (ii)

$\frac{E_1}{T_1^4} = \frac{E_2}{E_2^4}$

or $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4$

$\frac{E_1}{E_2} = \left(\frac{300}{1200}\right)^4$

$\frac{E_1}{E_2} = \left(\frac{1}{4}\right)^4$

$\frac{E_1}{E_2} = \frac{1}{256}$

or $E_1 : E_2 = 1 : 256$

11. According to the first law of thermodynamics,

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

$\Rightarrow C = \frac{\Delta Q}{\Delta T} = \frac{\Delta W}{\Delta T} + \frac{\Delta U}{\Delta T}$

$\Rightarrow C = \frac{\Delta W}{\Delta T} + C_V$

$C = \frac{p\Delta V}{\Delta T} + C_V$ ....(i)

For the process,

$pV = RT$

$\Rightarrow V = \frac{RT}{p} = \frac{RT^2}{a}$

$\Rightarrow \frac{\Delta V}{\Delta T} = \frac{dV}{dT} = \frac{2RT}{a}$ ......(ii)

Substituting the values of $Eq. (ii)$ in $Eq(i)$,

$\Rightarrow p\left(\frac{2RT}{a}\right) + C_V = \frac{a}{T}\left(\frac{2RT}{a}\right) + C_V$

$\Rightarrow \quad C = 2R + C_V = 2R + \frac{3}{2}R = \frac{7}{2}R$

12. Rate of boiling of water = m= 6.0 Kg / min

m $= \frac{6\times10^3 g}{60\,\text{sec}}$ = 100 g/s

L = latent heat of vaporization of water

using Q = m L

Q $= \frac{100g}{s} \times \frac{2256J}{g}$

Q = 225 600 J/s

T_1 = Temperature of hot junction

T_2 = Temperature of cold junction = 100 ^{0}C

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

K = constant

Q = flow of heat

A = area of cross-section

t = time taken for flow of heat

x = Distance between hot and cold junction

$225600 = \frac{\mathrm{KA(T_1 - T_2)}}{\mathrm{x}}$

$(T_1 - T_2) = \frac{225600 \times x}{KA}$

Now, x = 1.0 cm = 1.0 $\times$ 10^{-2} m

K = 109 J/sec/m/ ^{0}C

A = 0.15 m^2

t = 1 s

$\mathrm{T_1 - T_2} = \frac{225600 \times 1.0 \times 10^{-2}}{109 \times 0.15}$

T_1 - T_2 = 137.98

T_1 = 137.98 +T_2

T_1 = 137.98 + 100

T_1 = 237.98 ^{0}C

13. Suppose the initial temperatures of hot and cold reservoirs be T_1, and T_2. The efficiency of the Carnot engine,

$\eta = \frac{T_1 - T_2}{T_1}$ ....(i)

As given the temperature of both the reservoirs is raised by equal amount t, therefore

$T_1' = T_1 + t$ and $T_2' = T_2 + t$.

The final efficiency of the Carnot engine,

$\eta' = \frac{T_1' - T_2'}{T_1'} = \frac{(T_1 + t) - (T_2 + t)}{(T_1 + t)}$

$= \frac{T_1 - T_2}{(T_1 + t)}$ ....(ii)

Dividing $Eq.\ (ii)$ by $Eq.\ (i)$,

$\Rightarrow \frac{\eta'}{\eta} = \frac{\left(\frac{T_1 - T_2}{T_1 + t}\right)}{\left(\frac{T_1 - T_2}{T_1}\right)} = \frac{T_1}{T_1 + t}$ ....(iii)

As, $\eta' < \eta$,the efficiency decreases.

14. For an ideal gas,

$\frac{C_p}{C_V} = \gamma$ and $C_p - C_v = R$

Combining above equations,

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

$(C_V)_A = \frac{R}{\frac{5}{2} - 1} = \frac{3}{2}R$

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

$(C_V)_{\text{mix}} = \frac{R}{\frac{19}{13} - 1} = \frac{13}{6}R$

Using law of conservation of energy

$U_{mix} = U_A + U_B$

or, $\Delta U_{\text{mix}} = \Delta U_A + \Delta U_B$

$\Rightarrow (\mu_A + \mu_B)(C_V)_{\text{mix}} \Delta T = \mu_A (C_V)_A \Delta T + \mu_B (C_V)_B \Delta T$

$\Rightarrow (C_V)_{\text{mix}} = \frac{\mu_A (C_V)_A + \mu_B (C_V)_B}{\mu_A + \mu_B}$

$\Rightarrow \frac{13}{6}R = \frac{1 \times \frac{3}{2}R + \mu_B \times \frac{5}{2}R}{1 + \mu_B}$

$\Rightarrow 13 + 13\mu_B = 9 + 15\mu_B$

$\Rightarrow \mu_B = 2\text{g} - \text{mol}$

15. An **adiabatic process** is one in which no heat is gained or lost by the system. The first law of thermodynamics with Q=0 shows that all the change in internal energy is in the form of work done.

Slope of graph at $(V_0, P_0) = \left(\frac{dP}{dV}\right)_{(V_e P_0)}$

$P = f(V)$ for adiabatic process PV^{γ} = constant (K)

Or $P = \frac{K}{V^\gamma}$ or $\frac{dP}{dV} = K(-\gamma)V^{-\gamma-1}$

$\frac{dP}{dV} = -\gamma P V^{\gamma} V^{-\gamma} V^{-1} = -\frac{\gamma P}{V}$

$\left(\frac{dP}{dV}\right)_{(P_o, V_0)} = \frac{-\gamma P_0}{V_0}$ Heat absorbed by in the process $P = f(V)$

$dQ = dU + dW$

$dQ = nC_V dT + PdV \ldots (i)$

$PV = nRT$

$T = \frac{PV}{nR} = \frac{V}{nR} f(V)$

$\frac{dT}{dV} = \frac{1}{nR}[f(V) + Vf'(V)]$

$\frac{dQ}{dV} = nCv\frac{dT}{dV} + P \cdot \frac{dV}{dV} = \frac{nCv}{nR}[f(V) + Vf'(V)] + P$

$\left(\frac{dQ}{dV}\right)_{V-V_0} = \frac{Cv}{R}[f(V_0)+V_0f'(V_0)]+f(V_0)\ [\because P=f(V)\,\text{given}]$

$= f(V_0)\left[\frac{C_V}{R}+1\right]+V_0f'(V_0)\frac{C_V}{R}$

$C_P-C_V=R \Rightarrow \frac{C_P}{C_V}-1=\frac{R}{C_V}$

$\therefore \gamma-1=\frac{R}{C_V} \Rightarrow C_V=\frac{R}{\gamma-1} \Rightarrow \frac{C_V}{R}=\frac{1}{\gamma-1}$

$\left(\frac{dQ}{dV}\right)_{V-V_0}=f(V_0)\left[\frac{1}{\gamma-1}+1\right]+V_0f'(V_0)\frac{1}{\gamma-1}$

$= f(V_0)\left[\frac{1+\gamma-1}{\gamma-1}\right]+\frac{V_0f'(V_0)}{\gamma-1}$

$= \frac{\gamma}{(\gamma-1)}f(V_0)+V_0\frac{f'(V_0)}{\gamma-1}$

$= \frac{1}{(\gamma-1)}[\gamma f(V_0)+V_0f'(V_0)]\ (\because f(V_0)=P_0)$

$\left(\frac{dQ}{dV}\right)_{V-V_0} = \frac{1}{(r-1)}[\gamma P_0+V_0f'(V_0)]$

$\therefore \left(\frac{dQ}{dV}\right)_{V-V_0} > 1 \therefore \text{ and } \gamma>1 \text{ so } \frac{1}{\gamma-1} \text{ is } +ve$

$\therefore \gamma P_0+V_0f'(V_0)>0$

$V_0f'(V_0)>-\gamma P_0$

$f'(V_0)>\frac{-\gamma P_0}{V_0}.$