CHAPTER

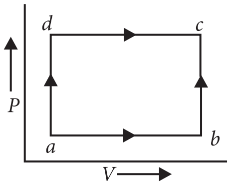
12

Thermodynamics

12.5 First Law of Thermodynamics

1. A sample of 0.1 g of water at 100°C and normal pressure (1.013×10^5 N m^{-2}) requires 54 cal of heat energy to convert to steam at 100°C. If the volume of the steam produced is 167.1 cc, the change in internal energy of the sample, is
(a) 104.3 J (b) 208.7 J
(c) 42.2 J (d) 84.5 J *(NEET 2018)*

2. A system is taken from state *a* to state *c* by two paths *adc* and *abc* as shown in the figure. The internal energy at *a* is U_a = 10 J. Along the path *adc* the amount of heat absorbed dQ_1 = 50 J and the work obtained dW_1 = 20 J whereas along the path *abc* the heat absorbed dQ_2 = 36 J. The amount of work along the path *abc* is



(a) 10 J (b) 12 J (c) 36 J (d) 6 J
(Karnataka NEET 2013)

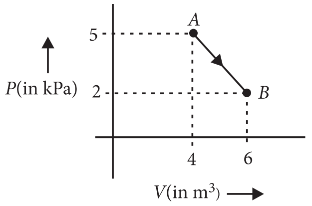
3. The internal energy change in a system that has absorbed 2 kcal of heat and done 500 J of work is
(a) 6400 J (b) 5400 J
(c) 7900 J (d) 8900 J *(2009)*

4. 110 joule of heat is added to a gaseous system whose internal energy is 40 J, then the amount of external work done is
(a) 150 J (b) 70 J
(c) 110 J (d) 40 J *(1993)*

5. First law of thermodynamics is consequence of conservation of
(a) work (b) energy
(c) heat (d) all of these *(1988)*

12.6 Specific Heat Capacity

6. One mole of an ideal diatomic gas undergoes a transition from *A* to *B* along a path *AB* as shown in the figure. The change in internal energy of the gas during the transition is



(a) 20 J (b) −12 kJ
(c) 20 kJ (d) −20 kJ *(2015 Cancelled)*

7. If c_p and c_v denote the specific heats per unit mass of an ideal gas of molecular weight *M*, then
(a) $c_p - c_v = R/M^2$ (b) $c_p - c_v = R$
(c) $c_p - c_v = R/M$ (d) $c_p - c_v = MR$
where *R* is the molar gas constant. *(Mains 2010)*

8. If the ratio of specific heat of a gas at constant pressure to that at constant volume is γ, the change in internal energy of a mass of gas, when the volume changes from *V* to 2*V* at constant pressure *P*, is
(a) $\dfrac{PV}{(\gamma-1)}$ (b) PV
(c) $\dfrac{R}{(\gamma-1)}$ (d) $\dfrac{\gamma PV}{(\gamma-1)}$ *(1998)*

9. One mole of an ideal gas requires 207 J heat to rise the temperature by 10 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same 10 K, the heat required is
(Given the gas constant *R* = 8.3 J/mole K)
(a) 198.7 J (b) 29 J
(c) 215.3 J (d) 124 J *(1990)*

12.7 Thermodynamic State Variables and Equation of State

10. A cylinder contains hydrogen gas at pressure of 249 kPa and temperature 27°C. Its density is (R = 8.3 J mol^{-1} K^{-1})
(a) 0.5 kg/m^3 (b) 0.2 kg/m^3
(c) 0.1 kg/m^3 (d) 0.02 kg/m^3 *(NEET 2020)*

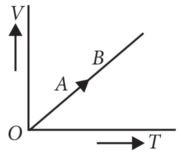
11. Which of the following is not thermodynamical function ?
(a) Enthalpy (b) Work done
(c) Gibb's energy (d) Internal energy *(1993)*

12.8 Thermodynamic Processes

12. Two cylinders *A* and *B* of equal capacity are connected to each other via a stopcock. *A* contains an ideal gas at standard temperature and pressure. *B* is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. The process is
(a) isothermal (b) adiabatic
(c) isochoric (d) isobaric *(NEET 2020)*

13. In which of the following processes, heat is neither absorbed nor released by a system?
(a) isochoric (b) isothermal
(c) adiabatic (d) isobaric *(NEET 2019)*

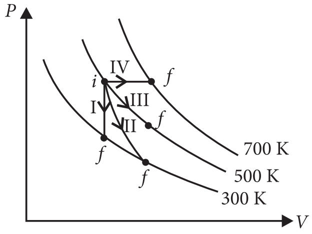
14. The volume (*V*) of amonatomic gas varies with its temperature (*T*), as shown in the graph. The ratio of work done by the gas, to the heat absorbed by it, when it undergoes a change from state *A* to state *B*, is



(a) 2/5
(b) 2/3
(c) 1/3
(d) 2/7

(NEET 2018)

15. Thermodynamic processes are indicated in the following diagram.



Match the following.

	Column-1		**Column-2**
P.	Process I	A.	Adiabatic
Q.	Process II	B.	Isobaric
R.	Process III	C.	Isochoric
S.	Process IV	D.	Isothermal

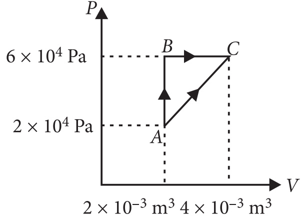
(a) P → C, Q → A, R → D, S → B
(b) P → C, Q → D, R → B, S → A
(c) P → D, Q → B, R → A, S → C
(d) P → A, Q → C, R → D, S → B *(NEET 2017)*

16. One mole of an ideal monatomic gas undergoes a process described by the equation PV^3 = constant. The heat capacity of the gas during this process is
(a) $\frac{3}{2}R$ (b) $\frac{5}{2}R$ (c) $2R$ (d) R
(NEET-II 2016)

17. A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then
(a) Compressing the gas isothermally or adiabatically will require the same amount of work.
(b) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.
(c) Compressing the gas isothermally will require more work to be done.
(d) Compressing the gas through adiabatic process will require more work to be done.
(NEET-I 2016)

18. An ideal gas is compressed to half its initial volume by means of several processes. Which of the process results in the maximum work done on the gas?
(a) Isochoric (b) Isothermal
(c) Adiabatic (d) Isobaric *(2015)*

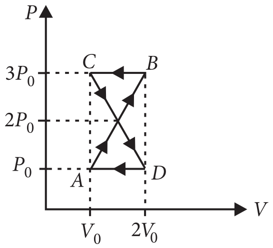
19. Figure below shows two paths that may be taken by a gas to go from a state *A* to a state *C*. In process *AB*, 400 J of heat is added to the system and in process *BC*, 100 J of heat is added to the system. The heat absorbed by the system in the process *AC* will be



(a) 460 J (b) 300 J (c) 380 J (d) 500 J
(2015 Cancelled)

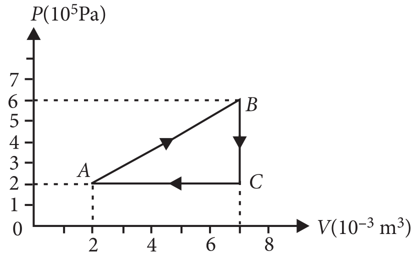
20. A monatomic gas at a pressure *P*, having a volume *V* expands isothermally to a volume 2*V* and then adiabatically to a volume 16*V*. The final pressure of the gas is (Take $\gamma = 5/3$)
(a) 64*P* (b) 32*P* (c) *P*/64 (d) 16*P* *(2014)*

21. A thermodynamic system undergoes cyclic process *ABCDA* as shown in figure. The work done by the system in the cycle is



(a) P_0V_0 (b) $2P_0V_0$
(c) $\frac{P_0V_0}{2}$ (d) zero *(2014)*

22. A gas is taken through the cycle $A \rightarrow B \rightarrow C \rightarrow A$, as shown. What is the net work done by the gas?



(a) Zero (b) – 2000 J
(c) 2000 J (d) 1000 J *(NEET 2013)*

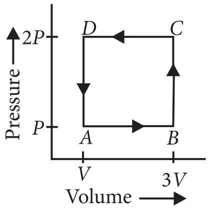
23. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is

(a) 5/3 (b) 3/2
(c) 4/3 (d) 2 *(NEET 2013)*

24. Which of the following relations does not give the equation of an adiabatic process, where terms have their usual meaning?

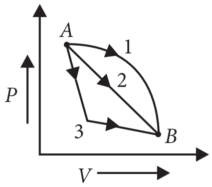
(a) $P^{1-\gamma}T^{\gamma}$ = constant
(b) PV^{γ} = constant
(c) $TV^{\gamma-1}$ = constant
(d) $P^{\gamma}T^{1-\gamma}$ = constant *(Karnataka NEET 2013)*

25. A thermodynamic system is taken through the cycle *ABCD* as shown in figure. Heat rejected by the gas during the cycle is



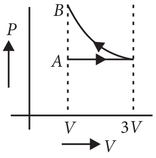
(a) $2PV$ (b) $4PV$ (c) $\frac{1}{2}PV$ (d) PV *(2012)*

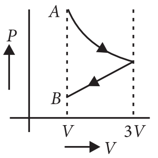
26. An ideal gas goes from state *A* to state *B* via three different processes as indicated in the *P*-*V* diagram. If Q_1, Q_2, Q_3 indicate the heat absorbed by the gas along the three processes and ΔU_1, ΔU_2, ΔU_3 indicate the change in internal energy along the three processes respectively, then

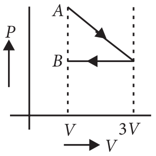


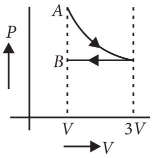
(a) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(b) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(c) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$
(d) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$ *(Mains 2012)*

27. One mole of an ideal gas goes from an initial state *A* to final state *B* via two processes : It first undergoes isothermal expansion from volume *V* to 3*V* and then its volume is reduced from 3*V* to *V* at constant pressure. The correct *P*-*V* diagram representing the two processes is

(a)


(b)


(c)


(d)


(2012)

28. During an isothermal expansion, a confined ideal gas does –150 J of work against its surroundings. This implies that

(a) 150 J of heat has been removed from the gas
(b) 300 J of heat has been added to the gas
(c) no heat is transferred because the process is isothermal
(d) 150 J of heat has been added to the gas. *(2011)*

29. A mass of diatomic gas ($\gamma = 1.4$) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in the final state is

(a) 8 atm (b) 28 atm
(c) 68.7 atm (d) 256 atm *(Mains 2011)*

30. If ΔU and ΔW represent the increase in internal energy and work done by the system respectively in a thermodynamical process, which of the following is true?

(a) $\Delta U = -\Delta W$, in an adiabatic process
(b) $\Delta U = \Delta W$, in an isothermal process
(c) $\Delta U = \Delta W$, in an adiabatic process
(d) $\Delta U = -\Delta W$, in an isothermal process *(2010)*

31. A monatomic gas at pressure P_1 and volume V_1 is compressed adiabatically to $\frac{1}{8}$th of its original volume. What is the final pressure of the gas?

(a) $64P_1$ (b) P_1 (c) $16P_1$ (d) $32P_1$
(Mains 2010)

32. In thermodynamic processes which of the following statements is not true?

(a) In an isochoric process pressure remains constant.
(b) In an isothermal process the temperature remains constant.
(c) In an adiabatic process PV^{γ} = constant.
(d) In an adiabatic process the system is insulated from the surroundings. *(2009)*

33. If *Q*, *E* and *W* denote respectively the heat added, change in internal energy and the work done in a closed cyclic process, then

(a) $E = 0$ (b) $Q = 0$
(c) $W = 0$ (d) $Q = W = 0$ *(2008)*

34. One mole of an ideal gas at an initial temperature of T K does $6R$ joule of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be
(a) $(T + 2.4)$ K (b) $(T - 2.4)$ K
(c) $(T + 4)$ K (d) $(T - 4)$ K *(2004)*

35. An ideal gas at 27°C is compressed adiabatically to 8/27 of its original volume. The rise in temperature is (Take $\gamma = 5/3$)
(a) 275 K (b) 375 K
(c) 475 K (d) 175 K *(1999)*

36. We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true?
(a) $\Delta U = -W$ in an isothermal process
(b) $\Delta U = W$ in an isothermal process
(c) $\Delta U = -W$ in an adiabatic process
(d) $\Delta U = W$ in an adiabatic process *(1998)*

37. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest, when the expansion is
(a) adiabatic (b) equal in all cases
(c) isothermal (d) isobaric. *(1997)*

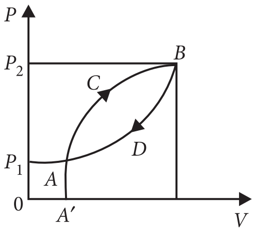
38. An ideal gas, undergoing adiabatic change, has which of the following pressure temperature relationship?
(a) $P^{\gamma}T^{1-\gamma}$ = constant (b) $P^{1-\gamma}T^{\gamma}$ = constant
(c) $P^{\gamma-1}T^{\gamma}$ = constant (d) $P^{\gamma}T^{\gamma-1}$ = constant.
(1996)

39. A diatomic gas initially at 18°C is compressed adiabatically to one eighth of its original volume. The temperature after compression will be
(a) 395.4°C (b) 144°C
(c) 18°C (d) 887.4°C *(1996)*

40. In an adiabatic change, the pressure and temperature of a monatomic gas are related as $P \propto T^C$, where C equals
(a) 3/5 (b) 5/3
(c) 2/5 (d) 5/2 *(1994)*

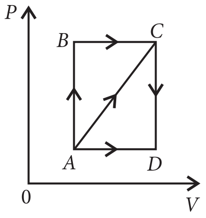
41. An ideal gas A and a real gas B have their volumes increased from V to $2V$ under isothermal conditions. The increase in internal energy
(a) will be same in both A and B
(b) will be zero in both the gases
(c) of B will be more than that of A
(d) of A will be more than that of B. *(1993)*

42. A thermodynamic system is taken from state A to B along ACB and is brought back to A along BDA as shown in the PV diagram. The net work done during the complete cycle is given by the area



(a) $P_1ACBP_2P_1$ (b) $ACBB'A'A$
(c) $ACBDA$ (d) $ADBB'A'A$ *(1992)*

43. A thermodynamic process is shown in the figure. The pressure and volumes corresponding to some points in the figure are



$P_A = 3 \times 10^4$ Pa; $V_A = 2 \times 10^{-3}$ m^3;
$P_B = 8 \times 10^4$ Pa; $V_D = 5 \times 10^{-3}$ m^3.
In the process AB, 600 J of heat is added to the system and in process BC, 200 J of heat is added to the system. The change in internal energy of the system is process AC would be
(a) 560 J (b) 800 J
(c) 600 J (d) 640 J *(1991)*

12.9 Heat Engines

44. The efficiency of an ideal heat engine working between the freezing point and boiling point of water, is
(a) 26.8% (b) 20% (c) 6.25% (d) 12.5%
(NEET 2018)

12.10 Refrigerators and Heat Pumps

45. The temperature inside a refrigerator is t_2°C and the room temperature is t_1°C. The amount of heat delivered to the room for each joule of electrical energy consumed ideally will be
(a) $\dfrac{t_1}{t_1 - t_2}$ (b) $\dfrac{t_1 + 273}{t_1 - t_2}$
(c) $\dfrac{t_2 + 273}{t_1 - t_2}$ (d) $\dfrac{t_1 + t_2}{t_1 + 273}$ *(NEET-II 2016)*

46. A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the temperature of the refrigerated space constant. The power required is (Take 1 cal = 4.2 Joules)
(a) 236.5 W (b) 2365 W
(c) 2.365 W (d) 23.65 W *(NEET-I 2016)*

47. The coefficient of performance of a refrigerator is 5. If the temperature inside freezer is –20°C, the temperature of the surroundings to which it rejects heat is

(a) 11°C (b) 21°C
(c) 31°C (d) 41°C *(2015)*

12.12 Reversible and Irreversible Processes

48. Which of the following processes is reversible?
(a) Transfer of heat by conduction
(b) Transfer of heat by radiation
(c) Isothermal compression
(d) Electrical heating of a nichrome wire *(2005)*

12.13 Carnot Engine

49. A carnot engine having an efficiency of 1/10 as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is
(a) 90 J (b) 99 J (c) 100 J (d) 1 J
(NEET 2017, 2015 cancelled)

50. Two Carnot engines *A* and *B* are operated in series. The engine *A* receives heat from the source at temperature T_1 and rejects the heat to the sink at temperature *T*. The second engine *B* receives the heat at temperature *T* and rejects to its sink at temperature T_2. For what value of *T* the efficiencies of the two engines are equal
(a) $\frac{T_1 - T_2}{2}$ (b) $T_1 T_2$
(c) $\sqrt{T_1 T_2}$ (d) $\frac{T_1 + T_2}{2}$
(Karnataka NEET 2013)

51. An engine has an efficiency of 1/6. When the temperature of sink is reduced by 62°C, its efficiency is doubled. Temperatures of the source is
(a) 37°C (b) 62°C
(c) 99°C (d) 124°C *(2007)*

52. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased so as to increase its efficiency by 50% of original efficiency?
(a) 380 K (b) 275 K
(c) 325 K (d) 250 K *(2006)*

53. An ideal gas heat engine operates in Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cal of heat at higher temperature. Amount of heat converted to work is
(a) 4.8×10^4 cal (b) 6×10^4 cal
(c) 2.4×10^4 cal (d) 1.2×10^4 cal *(2005)*

54. An ideal gas heat engine operates in a Carnot cycle between 227°C and 127°C. It absorbs 6 kcal at the higher temperature. The amount of heat (in kcal) converted into work is equal to
(a) 4.8 (b) 3.5
(c) 1.6 (d) 1.2 *(2003)*

55. The efficiency of Carnot engine is 50% and temperature of sink is 500 K. If temperature of source is kept constant and its efficiency raised to 60%, then the required temperature of sink will be
(a) 100 K (b) 600 K
(c) 400 K (d) 500 K *(2002)*

56. A scientist says that the efficiency of his heat engine which work at source temperature 127°C and sink temperature 27°C is 26%, then
(a) it is impossible
(b) it is possible but less probable
(c) it is quite probable
(d) data are incomplete. *(2001)*

57. The (*W*/*Q*) of a Carnot engine is 1/6, now the temperature of sink is reduced by 62°C, then this ratio becomes twice, therefore the initial temperature of the sink and source are respectively
(a) 33°C, 67°C (b) 37°C, 99°C
(c) 67°C, 33°C (d) 97 K, 37 K *(2000)*

58. The efficiency of a Carnot engine operating with reservoir temperature of 100°C and –23°C will be
(a) $\frac{373+250}{373}$ (b) $\frac{373-250}{373}$
(c) $\frac{100+23}{100}$ (d) $\frac{100-23}{100}$ *(1997)*

59. An ideal Carnot engine, whose efficiency is 40%, receives heat at 500 K. If its efficiency is 50%, then the intake temperature for the same exhaust temperature is
(a) 800 K (b) 900 K
(c) 600 K (d) 700 K *(1995)*

ANSWER KEY

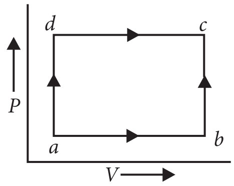
1.	(b)	**2.**	(d)	**3.**	(c)	**4.**	(b)	**5.**	(b)	**6.**	(d)	**7.**	(c)	**8.**	(a)	**9.**	(d)	**10.**	(b)
11.	(b)	**12.**	(b)	**13.**	(c)	**14.**	(a)	**15.**	(a)	**16.**	(d)	**17.**	(d)	**18.**	(c)	**19.**	(a)	**20.**	(c)
21.	(d)	**22.**	(d)	**23.**	(b)	**24.**	(d)	**25.**	(a)	**26.**	(a)	**27.**	(d)	**28.**	(d)	**29.**	(d)	**30.**	(a)
31.	(d)	**32.**	(a)	**33.**	(a)	**34.**	(d)	**35.**	(b)	**36.**	(c)	**37.**	(d)	**38.**	(b)	**39.**	(a)	**40.**	(d)
41.	(b)	**42.**	(c)	**43.**	(a)	**44.**	(a)	**45.**	(b)	**46.**	(a)	**47.**	(c)	**48.**	(c)	**49.**	(a)	**50.**	(c)
51.	(c)	**52.**	(d)	**53.**	(d)	**54.**	(d)	**55.**	(c)	**56.**	(a)	**57.**	(b)	**58.**	(b)	**59.**	(c)		

Hints & Explanations

1. **(b) :** Using first law of thermodynamics,
$\Delta Q = \Delta U + \Delta W$
$\Rightarrow$ $54 \times 4.18 = \Delta U + 1.013 \times 10^5 (167.1 \times 10^{-6} - 0)$
$\Rightarrow$ $\Delta U = 208.7$ J

2. **(d) :** According to first law of thermodynamics, $\delta Q = \delta U + \delta W$

Along the path *adc*, change in internal energy,



$\delta U_1 = \delta Q_1 - \delta W_1$
$= 50\text{ J} - 20\text{ J} = 30\text{ J}$

Along the path *abc*,
Change in internal energy,
$\delta U_2 = \delta Q_2 - \delta W_2$
$\delta U_2 = 36\text{ J} - \delta W_2$

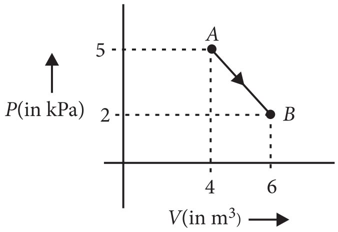
As change in internal energy is path independent.
$\therefore$ $\delta U_1 = \delta U_2 \Rightarrow 30\text{ J} = 36\text{ J} - \delta W_2$
$\delta W_2 = 36\text{ J} - 30\text{ J} = 6\text{ J}$

3. **(c) :** Heat energy given $dQ = dU + dW$ where dU is the change in internal energy and dW is the work done.
Given $dQ = 2$ kcal $= 2000 \times 4.2$ J and $dW = 500$ J
$\therefore$ $2000 \times 4.2 = dU + 500 \Rightarrow dU = 7900$ J

4. **(b) :** $\Delta Q = \Delta U + \Delta W$
$\Rightarrow$ $\Delta W = \Delta Q - \Delta U = 110 - 40 = 70$ J

5. **(b)**

6. **(d) :**



We know, $\Delta U = nC_v \Delta T$

$$= n\left(\frac{5R}{2}\right)(T_B - T_A) \qquad \left[\text{for diatomic gas}, C_v = \frac{5R}{2}\right]$$

$$= \frac{5nR}{2}\left(\frac{P_BV_B}{nR} - \frac{P_AV_A}{nR}\right) \qquad [\because PV = nRT]$$

$$= \frac{5}{2}(P_BV_B - P_AV_A) = \frac{5}{2}(2 \times 10^3 \times 6 - 5 \times 10^3 \times 4)$$

$$= \frac{5}{2}(-8 \times 10^3) = -20\text{ kJ}$$

7. **(c) :** Let C_V and C_P be molar specific heats of the ideal gas at constant volume and constant pressure, respectively, then
$C_P = Mc_p$ and $C_V = Mc_v$
$C_P - C_V = R$
$\therefore$ $Mc_p - Mc_v = R \Rightarrow c_p - c_v = R/M$

8. **(a) :** Change in internal energy, $\Delta U = nC_V \Delta T$

$$= \frac{nR\Delta T}{(\gamma - 1)} = \frac{nP\Delta V}{(\gamma - 1)} = \frac{nP(2V - V)}{\gamma - 1}$$

For one mole, $n = 1$
$\therefore$ $\Delta U = PV/(\gamma - 1)$

9. **(d) :** Using $C_P - C_V = R$,
C_P is heat needed for raising by 10 K.
$\therefore$ $C_P = 20.7$ J/mole K
Given $R = 8.3$ J/mole K
$\therefore$ $C_V = 20.7 - 8.3 = 12.4$ J/mole K
$\therefore$ For raising by 10 K = 124 J.

10. **(b) :** Here, $P = 249$ kPa $= 249 \times 10^3$ Pa
$T = 27°\text{C} = 27 + 273 = 300$ K
$M = 2 \times 10^{-3}$ kg
Equation of state, $PV = nRT$

or $PM = \rho RT$ $\qquad \left[\because n = \frac{m}{M}\right]$

or $\rho = \dfrac{PM}{RT}$

Substituting the values,

$$\rho = \frac{(249 \times 10^3)(2 \times 10^{-3})}{8.3 \times 300} = 0.2\text{ kg/m}^3$$

11. **(b) :** Work done is not a thermodynamical function.

12. **(b) :** Since, the entire system is thermally insulated, no heat flows into the system. When the stopcock is removed, the gas expands adiabatically.

13. **(c) :** Adiabatic process is the process in which no exchange of heat energy takes place between the gas and the surroundings,
i.e., $\Delta Q = 0$.

14. **(a) :** Given process is isobaric.
$\therefore$ $dQ = nC_p dT$; where C_p is specific heat at constant pressure.

or $dQ = n\left(\frac{5}{2}R\right)dT$

Also, $dW = PdV = nRdT$ $\qquad (\because PV = nRT)$

$$\text{Required ratio} = \frac{dW}{dQ} = \frac{nRdT}{n\left(\frac{5}{2}R\right)dT} = \frac{2}{5}$$

15. **(a) :** In process I, volume is constant.
$\therefore$ Process I → Isochoric; P → C
As slope of curve II is more than the slope of curve III.
Process II → Adiabatic and
Process III →Isothermal
$\therefore$ Q → A, R → D

In process IV, pressure is constant.
Process IV → Isobaric; S → B

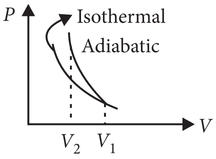
16. (d) : Process described by the equation,
PV^3 = constant
For a polytropic process, PV^{α} = constant

$$C = C_V + \frac{R}{1-\alpha} = \frac{3}{2}R + \frac{R}{1-3} = R$$

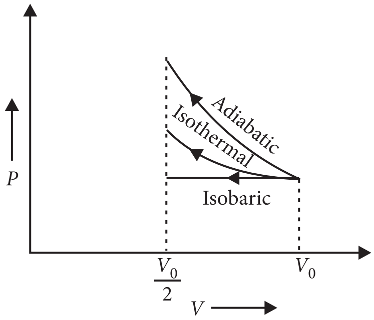
17. (d) : $V_1 = V$, $V_2 = V/2$

On *P-V* diagram, Area under adiabatic curve > Area under isothermal curve.

So, compressing the gas through adiabatic process will require more work to be done.



18. (c) :

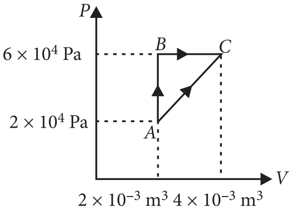


The *P-V* diagram of an ideal gas compressed from its initial volume V_0 to $\frac{V_0}{2}$ by several processes is shown in the figure.

Work done on the gas = Area under *P–V* curve.

As area under the *P–V* curve is maximum for adiabatic process, so work done on the gas is maximum for adiabatic process.

19. (a) : As initial and final points for two paths are same so



$\Delta U_{ABC} = \Delta U_{AC}$

AB is isochoric process.

$\Delta W_{AB} = 0$

$\Delta Q_{AB} = \Delta U_{AB} = 400$ J

BC is isobaric process.

$\Delta Q_{BC} = \Delta U_{BC} + \Delta W_{BC}$

$100 = \Delta U_{BC} + 6 \times 10^4 (4 \times 10^{-3} - 2 \times 10^{-3})$

$100 = \Delta U_{BC} + 12 \times 10$

$\Delta U_{BC} = 100 - 120 = -20$ J

As, $\Delta U_{ABC} = \Delta U_{AC}$

$\Delta U_{AB} + \Delta U_{BC} = \Delta Q_{AC} - \Delta W_{AC}$

$$400 - 20 = \Delta Q_{AC} - (2 \times 10^4 \times 2 \times 10^{-3} + \frac{1}{2} \times 2 \times 10^{-3} \times 4 \times 10^4)$$

$\Delta Q_{AC} = 460$ J

20. (c) : First, isothermal expansion

$PV = P'(2V)$; $P' = \frac{P}{2}$

Then, adiabatic expansion

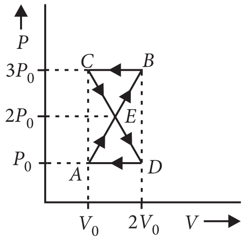
$P'(2V)^{\gamma} = P_f(16V)^{\gamma}$

(For adiabatic process, PV^{γ} = constant)

$$\frac{P}{2}(2V)^{5/3} = P_f\,(16V)^{5/3}$$

$$P_f = \frac{P}{2}\left(\frac{2V}{16V}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{2^3}\right)^{5/3} = \frac{P}{64}$$

21. (d) : In a cyclic process work done is equal to the area under the cycle and is positive if the cycle is clockwise and negative if cycle is anticlockwise.



As is clear from figure,

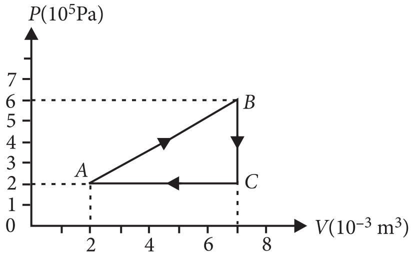
$$W_{AEDA} = +\text{area of } \Delta AED = +\frac{1}{2}P_0V_0$$

$$W_{BCEB} = -\text{Area of } \Delta BCE = -\frac{1}{2}P_0V_0$$

The net work done by the system is

$$W_{\text{net}} = W_{AEDA} + W_{BCEB} = +\frac{1}{2}P_0V_0 - \frac{1}{2}P_0V_0 = \text{zero}$$

22. (d) :



In a cyclic process, work done is equal to the area under the cycle and is positive if the cycle is clockwise and negative if the cycle is anticlockwise.

∴ The net work done by the gas is

W = Area of the cycle *ABCA*

$$= \frac{1}{2} \times (7-2) \times 10^{-3} \times (6-2) \times 10^5$$

$$= \frac{1}{2} \times 5 \times 10^{-3} \times 4 \times 10^5 = 10 \times 10^2 \text{ J} = 1000 \text{ J}$$

23. (b) : $P \propto T^3$; PT^{-3} = constant ...(i)

For an adiabatic process; $PT^{\gamma/1-\gamma}$ = constant ...(ii)

Comparing (i) and (ii), we get

$$\frac{\gamma}{1-\gamma} = -3;\ \gamma = -3 + 3\gamma \text{ or } \gamma = \frac{3}{2}$$

$$\text{As} \quad \gamma = \frac{C_p}{C_v} \quad \therefore \quad \frac{C_p}{C_v} = \frac{3}{2}$$

24. (d) : For an adiabatic process,

PV^{γ} = constant ...(i)

According to ideal gas equation

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

Putting value of *P* in (i), we get

$$\frac{nRT}{V}V^{\gamma} = \text{constant} ; \quad \therefore \quad TV^{\gamma-1} = \text{constant}$$

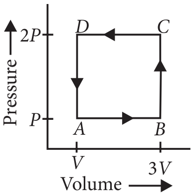
Again from the ideal gas equation

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

Putting value of V in (i), we get

$$P\left(\frac{nRT}{P}\right)^{\gamma} = \text{constant} ; P^{1-\gamma}\,T^{\gamma} = \text{constant}$$

25. (a) : In a cyclic process, $\Delta U = 0$. In a cyclic process work done is equal to the area under the cycle and is positive if the cycle is clockwise and negative if anticlockwise.



$\therefore \quad \Delta W = -$ Area of rectangle $ABCD = -P(2V) = -2PV$

According to first law of thermodynamics

$\Delta Q = \Delta U + \Delta W$ or $\Delta Q = \Delta W$ (As $\Delta U = 0$)

So, $\Delta Q = \Delta W = -2PV$

$\therefore \quad$ Heat rejected by the gas $= 2PV$

26. (a) : Change in internal energy is path independent and depends only on the initial and final states.

As the initial and final states in the three processes are same. Therefore,

$$\Delta U_1 = \Delta U_2 = \Delta U_3$$

Workdone, W = Area under P-V graph

As area under curve 1 > area under curve 2 > area under curve 3

$\therefore \quad W_1 > W_2 > W_3$

According to first law of thermodynamics,

$$Q = W + \Delta U$$

As $W_1 > W_2 > W_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

$\therefore \quad Q_1 > Q_2 > Q_3$

27. (d) **28. (d)**

29. (d) : For an adiabatic process, $\dfrac{T^{\gamma}}{P^{\gamma-1}} = \text{constant}$

$$\therefore \quad \left(\frac{T_i}{T_f}\right)^{\gamma} = \left(\frac{P_i}{P_f}\right)^{\gamma-1} ; \quad P_f = P_i\left(\frac{T_f}{T_i}\right)^{\frac{\gamma}{\gamma-1}} \quad \text{...(i)}$$

Here, $T_i = 27°\text{C} = 300$ K, $T_f = 927°\text{C} = 1200$ K

$P_i = 2$ atm, $\gamma = 1.4$

Substituting these values in eqn (i), we get

$$P_f = (2)\left(\frac{1200}{300}\right)^{\frac{1.4}{1.4-1}} = (2)(4)^{1.4/0.4}$$

$$= 2(2^2)^{7/2} = (2)(2)^7 = 2^8 = 256 \text{ atm}$$

30. (a) : According to first law of thermodynamics

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

where,

ΔQ = Heat supplied to the system

ΔU = Increase in internal energy of the system

ΔW = Work done by the system

For an adiabatic process

$\Delta Q = 0 \quad \therefore \quad \Delta U = -\Delta W$

For an isothermal process

$\Delta U = 0 \quad \therefore \quad \Delta Q = \Delta W$

Hence, option (a) is true.

31. (d) : Ideal gas equation, for an adiabatic process is

$$PV^{\gamma} = \text{constant} \quad \text{or} \quad P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

For monoatomic gas, $\gamma = \dfrac{5}{3}$

$$\therefore \quad P_1V_1^{5/3} = P_2\left(\frac{V_1}{8}\right)^{5/3}$$

$$\Rightarrow \quad P_2 = P_1 \times (2)^5 = 32\,P_1.$$

32. (a) : In isochoric process, it is volume that is kept constant. If pressure is kept constant, it is an isobaric process.

33. (a) : Internal energy depends only on the initial and final states of temperature and not on the path. In a cyclic process, as initial and final states are the same, change in internal energy is zero. Hence E is zero.

34. (d) : Work done in adiabatic process is given as

$$W = \frac{-1}{\gamma-1}(P_fV_f - P_iV_i)$$

$$6R = \frac{-1}{5/3-1}R(T_f - T_i) \qquad [\text{using } PV = RT]$$

$$\Rightarrow \quad T_f - T_i = -4 \quad \therefore \quad T_f = (T - 4)\text{ K}$$

35. (b) : $TV^{\gamma-1}$ = constant (adiabatic)

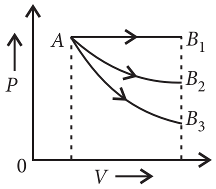
$\therefore \quad (300)\,(V_0)^{2/3} = (V_f)^{2/3}\,T$

$$T = 300\left(\frac{27}{8}\right)^{2/3} = 300 \times \left(\frac{3}{2}\right)^{3\times\frac{2}{3}} = \frac{300\times 9}{4} = 675\text{ K}$$

Temperature rise = 675 – 300 = 375 K

36. (c)

37. (d) : During expansion, work is performed by the gas. The isobaric expansion is represented by the horizontal straight line AB_1, since the adiabatic curve is steeper than the isothermal curve, the adiabatic expansion curve (AB_3) must lie below the isothermal curve (AB_2) as shown in the given figure Since area under AB_1, is maximum, the work done is maximum in case of isobaric expansion.



38. (b) : For the adiabatic change, PV^{γ} = constant.

And for ideal gas, $V = \dfrac{RT}{P} \propto \dfrac{T}{P}$.

Therefore $P^{1-\gamma}\,T^{\gamma}$ = constant.

39. (a) : Initial temperature (T_1) = 18°C = 291 K
and $V_2 = (1/8)\,V_1$
For adiabatic compression, $TV^{\gamma-1}$ = constant
or $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$.

Therefore $T_2 = T_1\left(\dfrac{V_1}{V_2}\right)^{\gamma-1}$

$$= 291 \times (8)^{1.4-1} = 291 \times (8)^{0.4}$$
$$= 291 \times 2.297 = 668.4 \text{ K} = 395.4°\text{C}$$

40. (d) : For adiabatic change, PV^{γ} = constant

$\Rightarrow\ P\left(\dfrac{RT}{P}\right)^{\gamma}$ = constant

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

Therefore, the value of constant, $C = \dfrac{\gamma}{(\gamma-1)}$.
For monoatomic gas, $\gamma = 5/3$.

Therefore $C = \dfrac{5/3}{(5/3)-1} = \dfrac{5/3}{2/3} = \dfrac{5}{2}$.

41. (b) : Under isothermal conditions, there is no change in internal energy.

42. (c) : Work done = Area under curve *ACBDA*

43. (a) : Since *AB* is a isochoric process. So no work is done. *BC* is isobaric process
$$W = P_B \times (V_D - V_A) = 240 \text{ J}$$
Therefore $\Delta Q = 600 + 200 = 800$ J
Using $\Delta Q = \Delta U + \Delta W$
$\Rightarrow\ \Delta U = \Delta Q - \Delta W = 800 - 240 = 560$ J

44. (a) : Efficiency of an ideal heat engine,
$$\eta = \left(1 - \frac{T_2}{T_1}\right)$$
Freezing point of water = 0°C = 273 K
Boiling point of water = 100°C = (100 + 273)K = 373 K
T_2 : Sink temperature = 273 K
T_1 : Source temperature = 373 K
$$\%\eta = \left(1 - \frac{T_2}{T_1}\right)\times 100 = \left(1 - \frac{273}{373}\right)\times 100$$
$$= \left(\frac{100}{373}\right)\times 100 = 26.8\%$$

45. (b) : Temperature inside refrigerator = t_2°C
Room temperature = t_1°C
For refrigerator,
$$\frac{\text{Heat given to high temperature } (Q_1)}{\text{Heat taken from lower temperature } (Q_2)} = \frac{T_1}{T_2}$$
$$\frac{Q_1}{Q_2} = \frac{t_1 + 273}{t_2 + 273}$$
$$\Rightarrow\ \frac{Q_1}{Q_1 - W} = \frac{t_1 + 273}{t_2 + 273} \text{ or } 1 - \frac{W}{Q_1} = \frac{t_2 + 273}{t_1 + 273}$$
or $\dfrac{W}{Q_1} = \dfrac{t_1 - t_2}{t_1 + 273}$

The amount of heat delivered to the room for each joule of electrical energy (W = 1 J)
$$Q_1 = \frac{t_1 + 273}{t_1 - t_2}$$

46. (a) : Given, T_2 = 4°C = 277 K, T_1 = 30°C = 303 K
Q_2 = 600 cal per second

Coefficient of performance, $\alpha = \dfrac{T_2}{T_1 - T_2}$
$$= \frac{277}{303 - 277} = \frac{277}{26}$$
Also, $\alpha = \dfrac{Q_2}{W}$

∴ Work to be done per second = power required
$$= W = \frac{Q_2}{\alpha} = \frac{26}{277} \times 600 \text{ cal per second}$$
$$= \frac{26}{277} \times 600 \times 4.2 \text{ J per second} = 236.5 \text{ W}$$

47. (c) : The coefficient of performance of a refrigerator is
$$\alpha = \frac{T_2}{T_1 - T_2}$$
where T_1 and T_2 are the temperatures of hot and cold reservoirs (in kelvin) respectively.
Here, $\alpha = 5$, T_2 = −20°C = −20 + 273 K = 253 K
T_1 = ?

∴ $5 = \dfrac{253 \text{ K}}{T_1 - 253 \text{ K}}$ or, $5T_1 - 5(253 \text{ K}) = 253$ K

$5T_1 = 253 \text{ K} + 5(253 \text{ K}) = 6(253 \text{ K})$

$T_1 = \dfrac{6}{5}(253 \text{K}) = 303.6 \text{ K} = 303.6 - 273$

$= 30.6°\text{C} \approx 31°\text{C}$

48. (c) : Isothermal compression is reversible, for example, Carnot cycle, heat engine.

49. (a) : The relation between coefficient of performance and efficiency of carnot engine is given as
$$\beta = \frac{1-\eta}{\eta}. \quad \text{Given } \eta = \frac{1}{10}, W = 10 \text{ J}$$
$$\beta = \frac{1 - \frac{1}{10}}{\frac{1}{10}} = \frac{9}{10}.10 = 9$$
Since, $\beta = \dfrac{Q_2}{W}$, where Q_2 is the amount of energy absorbed from the reservoir
∴ $Q_2 = \beta W = 9 \times 10 = 90$ J

50. (c) : Efficiency of a Carnot engine

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

where T_1 is the temperature of source and T_2 is the temperature of sink respectively.

For engine A, $\eta_A = 1-\frac{T}{T_1}$

For engine B, $\eta_B = 1-\frac{T_2}{T}$

As per question, $\eta_A = \eta_B$

$$\therefore\ 1-\frac{T}{T_1} = 1-\frac{T_2}{T} \Rightarrow \frac{T}{T_1} = \frac{T_2}{T} \text{ or } T = \sqrt{T_1T_2}$$

51. (c) : Efficiency of an engine, $\eta = 1-\frac{T_2}{T_1}$

where T_1 is the temperature of the source and T_2 is the temperature of the sink.

$$\therefore\ \frac{1}{6} = 1-\frac{T_2}{T_1} \quad \text{or,} \quad \frac{T_2}{T_1} = \frac{5}{6} \qquad \text{...(i)}$$

When the temperature of the sink is decreased by 62°C (or 62 K), efficiency becomes double.

Since, the temperature of the source remains unchanged

$$\therefore\ 2\times\frac{1}{6} = 1-\frac{(T_2-62)}{T_1} \quad \text{or,} \quad \frac{1}{3} = 1-\frac{(T_2-62)}{T_1}$$

$$\text{or,}\ \frac{2}{3} = \frac{T_2-62}{T_1} \quad \text{or,}\ 2T_1 = 3T_2 - 186$$

$$\text{or,}\ 2T_1 = 3\left[\frac{5}{6}\right]T_1 - 186 \quad [\text{using (i)}]$$

$$\therefore\ \left[\frac{5}{2}-2\right]T_1 = 186 \quad \text{or,} \quad \frac{T_1}{2} = 186$$

or, T_1 = 372 K = 99°C

52. (d) : Efficiency of a Carnot engine, $\eta = 1-\frac{T_2}{T_1}$

$$\text{or,}\ \frac{T_2}{T_1} = 1-\eta = 1-\frac{40}{100} = \frac{3}{5}$$

$$\therefore\ T_1 = \frac{5}{3}\times T_2 = \frac{5}{3}\times 300 = 500 \text{ K}$$

Increase in efficiency = 50% of 40% = 20%

New efficiency, η′ = 40% + 20% = 60%

$$\therefore\ \frac{T_2}{T_1'} = 1-\frac{60}{100} = \frac{2}{5}$$

$$T_1' = \frac{5}{2}\times T_2 = \frac{5}{2}\times 300 = 750 \text{ K.}$$

Increase in temperature of source = $T_1' - T_1$

= 750 – 500 = 250 K

53. (d) : $1-\frac{T_2}{T_1} = 1-\frac{Q_2}{Q_1} \Rightarrow 1-\frac{400}{500} = 1-\frac{Q_2}{6\times10^4}$

$\Rightarrow \frac{4}{5} = \frac{Q_2}{6\times10^4} \Rightarrow Q_2 = 4.8\times10^4$ cal

Net heat converted into work

= $6.0\times10^4 - 4.8\times10^4 = 1.2\times10^4$ cal

54. (d) : Efficiency of Carnot engine

$$= \frac{W}{Q_1} = 1-\frac{T_2}{T_1}$$

$$\frac{W}{6} = 1-\frac{400}{500} = \frac{1}{5} \Rightarrow W = \frac{6}{5} = 1.2 \text{ kcal}$$

55. (c) : Efficiency (η) of a carnot engine is given by

$\eta = 1-\frac{T_2}{T_1}$, where T_1 is the temperature of the source and T_2 is the temperature of the sink.

Here, T_2 = 500 K

$$\therefore\ 0.5 = 1-\frac{500}{T_1} \Rightarrow T_1 = 1000 \text{ K}.$$

Now, $\eta = 0.6 = 1-\frac{T_2'}{1000}$ (T_2' is the new sink temperature)

$\Rightarrow$ T_2' = 400 K.

56. (a) : Efficiency is maximum in Carnot engine which is an ideal engine.

$$\eta = \frac{400-300}{400}\times100\% = 25\%$$

∴ efficiency 26% is impossible for his heat engine.

57. (b) : $\frac{1}{6} = 1-\frac{T_2}{T_1}$ or $\frac{5}{6} = \frac{T_2}{T_1}$

$$\text{Now,}\ \frac{1}{3} = 1-\frac{T_2-62}{T_1} = 1-\frac{5}{6}+\frac{62}{T_1}$$

T_1 = 62 × 6 = 372 K = 99°C and T_2 = 310 K = 37°C

58. (b) : Reservoir temperature (T_1) = 100°C = 373 K and T_2 = – 23°C = 250 K.

The efficiency of a Carnot engine

$$\eta = \frac{T_1-T_2}{T_1} = \frac{373-250}{373}$$

59. (c) : Efficiency of Carnot engine (η_1) = 40% = 0.4

New efficiency (η_2) = 50 % = 0.5.

The efficiency (η) = $1-\frac{T_2}{T_1}$ or $\frac{T_2}{T_1} = 1-\eta$

For first case, $\frac{T_2}{500} = 1-0.4$ or T_2 = 300 K

For second case, $\frac{300}{T_1} = 1-0.5$ or T_1 = 600 K

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