DPP - Daily Practice Problems

Chapter-wise Sheets

Date :   **Start Time :**   **End Time :**

PHYSICS

CP11

SYLLABUS : Thermodynamics

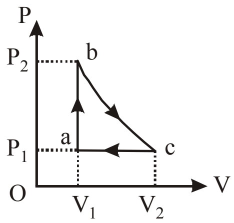
Max. Marks : 180   **Marking Scheme :** (+4) for correct & (–1) for incorrect answer   **Time : 60 min.**

INSTRUCTIONS : This Daily Practice Problem Sheet contains 45 MCQs. For each question only one option is correct. Darken the correct circle/ bubble in the Response Grid provided on each page.

1. The relation between *U*, *P* and *V* for an ideal gas in an adiabatic process is given by relation $U = a + bPV$. Find the value of adiabatic exponent (γ) of this gas

(a) $\frac{b+1}{b}$ (b) $\frac{b+1}{a}$ (c) $\frac{a+1}{b}$ (d) $\frac{a}{a+b}$

2. Carbon monoxide is carried around a closed cycle abc in which bc is an isothermal process as shown in the figure. The gas absorbs 7000 J of heat as its temperture increases from 300 K to 1000 K in going from a to b. The quantity of heat rejected by the gas during the process ca is



(a) 4200 J (b) 5000 J (c) 9000 J (d) 9800 J

3. A Carnot engine, having an efficiency of $\eta = 1/10$ 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) 100 J (b) 99 J (c) 90 J (d) 1 J

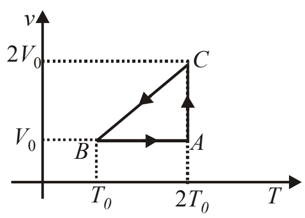
4. In a thermodynamic process, fixed mass of a gas is changed in such a manner that the gas release 20 J of heat and 8 J of work was done on the gas. If the initial internal energy of the gas was 30 J. Then the final internal energy will be

(a) 2 joule (b) 18 joule (c) 42 joule (d) 58 joule

5. A closed gas cylinder is divided into two parts by a piston held tight. The pressure and volume of gas in two parts respectively are (P, 5V) and (10P, V). If now the piston is left free and the system undergoes isothermal process, then the volumes of the gas in two parts respectively are

(a) 2V,4V (b) 3V,3V (c) 5V,V (d) $\frac{10}{11}V, \frac{20}{11}V$

6. The efficiency of an ideal gas with adiabatic exponent 'γ' for the shown cyclic process would be



(a) $\frac{(2\ln 2 - 1)}{\gamma/(\gamma-1)}$

(b) $\frac{(1 - 2\ln 2)}{\gamma/(\gamma-1)}$

(c) $\frac{(2\ln 2 + 1)}{\gamma/(\gamma-1)}$

(d) $\frac{(2\ln 2 - 1)}{\gamma/(\gamma+1)}$

7. A mass of diatomic gas (γ = 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 final state is

(a) 28 atm (b) 68.7 atm (c) 256 atm (d) 8 atm

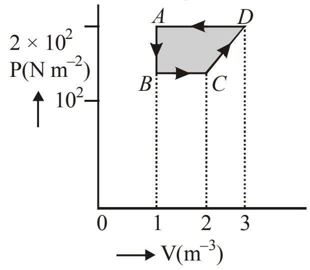
RESPONSE GRID

1. ⓐⓑⓒⓓ 2. ⓐⓑⓒⓓ 3. ⓐⓑⓒⓓ 4. ⓐⓑⓒⓓ 5. ⓐⓑⓒⓓ
6. ⓐⓑⓒⓓ 7. ⓐⓑⓒⓓ

Space for Rough Work

8. A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to $32\,V$, the efficiency of the engine is
(a) 0.5 (b) 0.75 (c) 0.99 (d) 0.25

9. The P-V diagram of a gas system undergoing cyclic process is shown here. The work done during isobaric compression is



(a) 100 J
(b) 200 J
(c) 600 J
(d) 400 J

10. During an adiabatic process of an ideal gas, if P is proportional to $\frac{1}{V^{1.5}}$, then the ratio of specific heat capacities at constant pressure to that at constant volume for the gas is
(a) 1.5 (b) 0.25 (c) 0.75 (d) 0.4

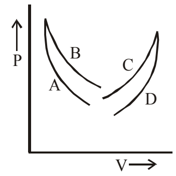
11. The work of 146 kJ is performed in order to compress one kilo mole of gas adiabatically and in this process the temperature of the gas increases by 7°C. The gas is ($R = 8.3\ J\,mol^{-1}\,K^{-1}$)
(a) diatomic
(b) triatomic
(c) a mixture of monoatomic and diatomic
(d) monoatomic

12. Consider a spherical shell of radius R at temperature T. The black body radiation inside it can be considered as an ideal gas of photons with internal energy per unit volume $u = \frac{U}{V} \propto T^4$ and pressure $p = \frac{1}{3}\left(\frac{U}{V}\right)$. If the shell now undergoes an adiabatic expansion the relation between T and R is :
(a) $T \propto \frac{1}{R}$ (b) $T \propto \frac{1}{R^3}$ (c) $T \propto e^{-R}$ (d) $T \propto e^{-3R}$

13. The specific heat capacity of a metal at low temperature (T) is given as $C(kJK^{-1}kg^{-1}) = 32\left(\frac{T}{400}\right)^3$. A 100 g vessel of this metal is to be cooled from 20 K to 4 K by a special refrigerator operating at room temperature (27°C). The amount of work required to cool in vessel is
(a) equal to 0.002 kJ
(b) greater than 0.148 kJ
(c) between 0.148 kJ and 0.028 kJ
(d) less than 0.028 kJ

14. 5.6 litre of helium gas at STP is adiabatically compressed to 0.7 litre. Taking the initial temperature to be T_1, the work done in the process is
(a) $\frac{9}{8}RT_1$ (b) $\frac{3}{2}RT_1$ (c) $\frac{15}{8}RT_1$ (d) $\frac{9}{2}RT_1$

15. Four curves A, B, C and D are drawn in the figure for a given amount of a gas. The curves which represent adiabatic and isothermal changes are
(a) C and D respectively
(b) D and C respectively
(c) A and B respectively
(d) B and A respectively



16. In an adiabatic process, the pressure is increased by $\frac{2}{3}\%$. If $\gamma = \frac{3}{2}$, then the volume decreases by nearly
(a) $\frac{4}{9}\%$ (b) $\frac{2}{3}\%$ (c) 1% (d) $\frac{9}{4}\%$

17. A reversible engine converts one-sixth of the heat input into work. When the temperature of the sink is reduced by 62°C, the efficiency of the engine is doubled. The temperatures of the source and sink are
(a) 99°C, 37°C (b) 80°C, 37°C
(c) 95°C, 37°C (d) 90°C, 37°C

18. A diatomic ideal gas is compressed adiabatically to $\frac{1}{32}$ of its initial volume. If the initial temperature of the gas is T_i (in Kelvin) and the final temperature is aT_i, the value of a is
(a) 8 (b) 4 (c) 3 (d) 5

19. When the state of a gas adiabatically changed from an equilibrium state A to another equilibrium state B an amount of work done on the stystem is 35 J. If the gas is taken from state A to B via process in which the net heat absorbed by the system is 12 cal, then the net work done by the system is (1 cal = 4.19 J)
(a) 13.2 J (b) 15.4 J (c) 12.6 J (d) 16.8 J

20. Calculate the work done when 1 mole of a perfect gas is compressed adiabatically. The initial pressure and volume of the gas are $10^5\ N/m^2$ and 6 litre respectively. The final volume of the gas is 2 litres. Molar specific heat of the gas at constant volume is 3R/2. [Given $(3)^{5/3} = 6.19$]
(a) –957 J (b) +957 J (c) – 805 J (d) + 805 J

21. A Carnot engine whose efficiency is 40%, receives heat at 500K. If the efficiency is to be 50%, the source temperature for the same exhaust temperature is
(a) 900 K (b) 600 K (c) 700 K (d) 800 K

22. 1 gm of water at a pressure of 1.01×10^5 Pa is converted into steam without any change of temperature. The volume of 1 g of steam is 1671 cc and the latent heat of evaporation is 540 cal. The change in internal energy due to evaporation of 1 gm of water is
(a) ≈ 167 cal (b) 500 cal (c) 540 cal (d) 581 cal

RESPONSE GRID					
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	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ
	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ

Space for Rough Work

23. One mole of an ideal gas at temperature T was cooled isochorically till the gas pressure fell from P to $\frac{P}{n}$. Then, by an isobaric process, the gas was restored to the initial temperature. The net amount of heat absorbed by the gas in the process is

(a) nRT (b) $\frac{RT}{n}$

(c) $RT(1-n^{-1})$ (d) $RT(n-1)$

24. A Carnot engine, having an efficiency of $\eta = \frac{1}{10}$ 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

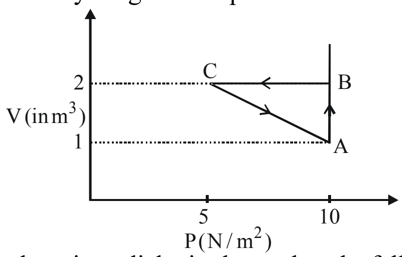
(a) 99 J (b) 90 J (c) 1 J (d) 100 J

25. The volume of an ideal gas is 1 litre and its pressure is equal to 72 cm of mercury column. The volume of gas is made 900 cm^3 by compressing it isothermally. The stress of the gas will be

(a) 8 cm of Hg (b) 7 cm of Hg

(c) 6 cm of Hg (d) 4 cm of Hg

26. An ideal gas is taken through the cycle $A \to B \to C \to A$, as shown in 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

27. An ideal gas undergoing adiabatic change has the following pressure-temperature relationship

(a) $P^{\gamma-1}T^{\gamma}$ = constant (b) $P^{\gamma}T^{\gamma-1}$ = constant

(c) $P^{\gamma}T^{1-\gamma}$ = constant (d) $P^{1-\gamma}T^{\gamma}$ = constant

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

(a) 2 joule (b) 18 joule (c) 42 joule (d) 58 joule

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

(a) 41°C (b) 11°C (c) 21°C (d) 31°C

30. Monatomic, diatomic and polyatomic ideal gases each undergo slow adiabatic expansions from the same initial volume and same initial pressure to the same final volume. The magnitude of the work done by the environment on the gas is

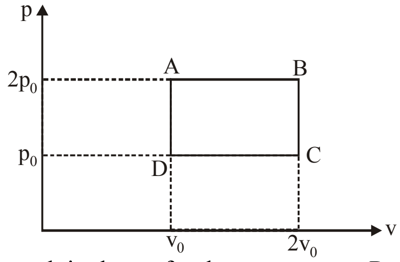
(a) the greatest for the polyatomic gas

(b) the greatest for the monatomic gas

(c) the greatest for the diatomic gas

(d) the question is irrelevant, there is no meaning of slow adiabatic expansion

31. The given p-v diagram represents the thermodynamic cycle of an engine, operating with an ideal monatomic gas. The amount of heat, extracted from the source in a single cycle is



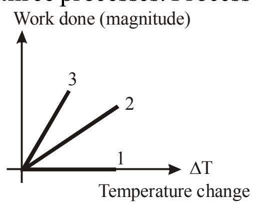
(a) p_0v_0

(b) $\left(\frac{13}{2}\right)p_0v_0$

(c) $\left(\frac{11}{2}\right)p_0v_0$

(d) $4p_0v_0$

32. For an ideal gas graph is shown for three processes. Process 1, 2 and 3 are respectively.



(a) Isobaric, adiabatic, isochoric

(b) Adiabatic, isobaric, isochoric

(c) Isochoric, adiabatic, isobaric

(d) Isochoric, isobaric, adiabatic

33. During an adiabatic process an object does 100J of work and its temperature decreases by 5K. During another process it does 25J of work and its temperature decreases by 5K. Its heat capacity for 2nd process is

(a) 20 J/K (b) 24 J/K (c) 15 J/K (d) 100 J/K

34. 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 joule)

(a) 2.365 W (b) 23.65 W (c) 236.5 W (d) 2365 W

35. A perfect gas goes from a state A to another state B by absorbing 8×10^5 J of heat and doing 6.5×10^5 J of external work. It is now transferred between the same two states in another process in which it absorbs 10^5 J of heat. In the second process

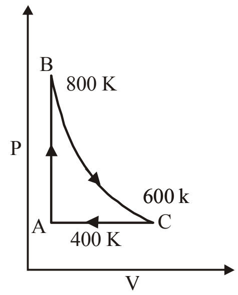
(a) work done by gas is 10^5 J

(b) work done on gas is 10^5 J

(c) work done by gas is 0.5×10^5 J

(d) work done on the gas is 0.5×10^5 J

36. One mole of a diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K, 800 K and 600 K respectively. Choose the correct statement:



(a) The change in internal energy in whole cyclic process is 250 R.

(b) The change in internal energy in the process CA is 700 R.

(c) The change in internal energy in the process AB is -350 R.

(d) The change in internal energy in the process BC is –500 R.

RESPONSE GRID					
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	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ	30. ⓐⓑⓒⓓ	31. ⓐⓑⓒⓓ	32. ⓐⓑⓒⓓ
	33. ⓐⓑⓒⓓ	34. ⓐⓑⓒⓓ	35. ⓐⓑⓒⓓ	36. ⓐⓑⓒⓓ	

Space for Rough Work

37. 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) $\frac{T_1-T_2}{2}$ (c) T_1T_2 (d) $\sqrt{T_1T_2}$

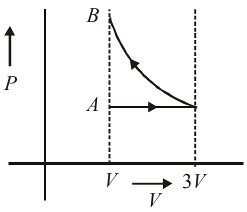
38. An ideal gas is initially at P_1, V_1 is expanded to P_2, V_2 and then compressed adiabatically to the same volume V_1 and pressure P_3. If W is the net work done by the gas in complete process which of the following is true ?

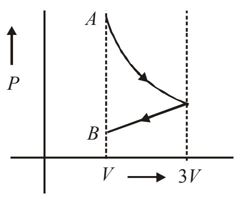
(a) $W > 0\,;\, P_3 > P_1$ (b) $W < 0\,;\, P_3 > P_1$
(c) $W > 0\,;\, P_3 < P_1$ (d) $W < 0\,;\, P_3 < P_1$

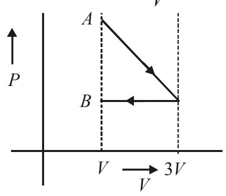
39. Which of the following statements is correct for any thermodynamic system ?

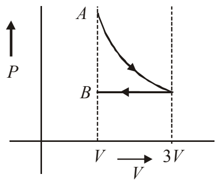
(a) The change in entropy can never be zero
(b) Internal energy and entropy are state functions
(c) The internal energy changes in all processes
(d) The work done in an adiabatic process is always zero.

40. 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 3V and then its volume is reduced from 3V to V at constant pressure. The correct P-V diagram representing the two processes is :

(a)


(b)


(c)


(d)


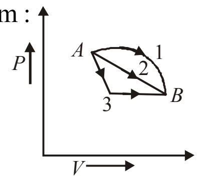
41. What will be the final pressure if an ideal gas in a cylinder is compressed adiabatically to $\frac{1}{3}$rd of its volume?

(a) Final pressure will be three times less than initial pressure.
(b) Final pressure will be three times more than initial pressure.
(c) Change in pressure will be more than three times the initial pressure.
(d) Change in pressure will be less than three times the initial pressure.

42. 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 will require more work to be done.
(b) Compressing the gas through adiabatic process will require more work to be done.
(c) Compressing the gas isothermally or adiabatically will require the same amount of work.
(d) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.

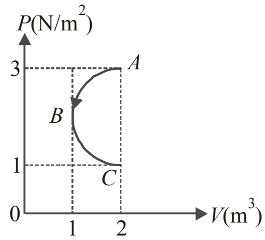
43. An ideal gas goes from state A to state B via three different processes as indicated in the P-V diagram :



If Q_1, Q_2, Q_3 indicate the heat a 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 $\Delta U_1 > \Delta U_2 > \Delta U_3$

44. In P-V diagram shown in figure ABC is a semicircle. The work done in the process ABC is



(a) 4 J
(b) $\frac{-\pi}{2}$J
(c) $\frac{\pi}{2}$J
(d) zero

45. For an isothermal expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal to

(a) $-\gamma^{1/2}\frac{\Delta V}{V}$ (b) $-\frac{\Delta V}{V}$ (c) $-\gamma\frac{\Delta V}{V}$ (d) $-\gamma^2\frac{\Delta V}{V}$

RESPONSE GRID					
	37. ⓐⓑⓒⓓ	38. ⓐⓑⓒⓓ	39. ⓐⓑⓒⓓ	40. ⓐⓑⓒⓓ	41. ⓐⓑⓒⓓ
	42. ⓐⓑⓒⓓ	43. ⓐⓑⓒⓓ	44. ⓐⓑⓒⓓ	45. ⓐⓑⓒⓓ	

DAILY PRACTICE PROBLEM DPP CHAPTERWISE CP11 - PHYSICS			
Total Questions	45	Total Marks	180
Attempted		Correct	
Incorrect		Net Score	
Cut-off Score	45	Qualifying Score	60
Success Gap = Net Score – Qualifying Score			
Net Score = (Correct × 4) – (Incorrect × 1)			

Space for Rough Work

DAILY PRACTICE PROBLEMS | PHYSICS SOLUTIONS | DPP/CP11

1. (a) $U = a + bPV$ ......(1)

In adiabatic change,

$$dU = -dW = \frac{nR}{\gamma-1}(T_2 - T_1) = \frac{nR}{\gamma-1}(dT)$$

$$\Rightarrow U = \int dU = \frac{nR}{\gamma-1}\int dT$$

or $$U = \left(\frac{nR}{\gamma-1}\right)T + a = \frac{PV}{\gamma-1} + a \text{ ......(2)}$$

where a is the constant of integration.

Comparing (1) and (2), we get

$$b = \frac{1}{\gamma-1} \Rightarrow \gamma = \frac{b+1}{b}.$$

2. (d) For path ab : $(\Delta U)_{ab} = 7000\,J$

By using $\Delta U = \mu C_V \Delta T$

$$7000 = \mu \times \frac{5}{2}R \times 700 \Rightarrow \mu = 0.48$$

For path ca :

$(\Delta Q)_{ca} = (\Delta U)_{ca} + (\Delta W)_{ca}$ ...(i)

$\because (\Delta U)_{ab} + (\Delta U)_{bc} + (\Delta U)_{ca} = 0$

$\because 7000 + 0 + (\Delta U)_{ca} = 0 \Rightarrow (\Delta U)_{ca} = -7000\,J$ ...(ii)

Also $(\Delta W)_{ca} = P_1(V_1 - V_2) = \mu R(T_1 - T_2)$

$= 0.48 \times 8.31 \times (300 - 1000) = -2792.16\text{J}$ ...(iii)

On solving equations (i), (ii) and (iii)

$(\Delta Q)_{ca} = -7000 - 2792.16 = -9792.16\,J \approx -9800\,J$

3. (c) The efficiency (η) of a Carnot engine and the coefficient of performance (β) of a refrigerator are related as

$$\beta = \frac{1-\eta}{\eta} \qquad \text{Here, } \eta = \frac{1}{10}$$

$$\therefore \beta = \frac{1 - \frac{1}{10}}{\left(\frac{1}{10}\right)} = 9.$$

Also, Coefficient of performance (β) is given by $\beta = \frac{Q_2}{W}$, where Q_2 is the energy absorbed from the reservoir.

or, $9 = \frac{Q_2}{10}$ $\qquad \therefore Q_2 = 90$ J.

4. (b) According to first law of thermodynamics,

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

ΔQ = heat absorbed by gas

ΔW = work done by gas.

$-20\text{J} = \Delta U - 8\text{J}$

$\Delta U = -12\text{J} = U_{Final} - U_{initial}$

$U_{initial} = 30\text{J}$.

$U_{Final} = 30 - 12 = 18\text{J}$.

5. (a) The volume on both sides will be so adjusted that the original pressure × volume is kept constant as the piston moves slowly (isothermal change)

$P5V = P'V'$ .... (1)

$10PV = P''V''$ .... (2)

From (1) and (2), $V'' = 2V'$

and from $V' + V'' = 6V$

$V' = 2V,\ V'' = 4V$

6. (a) $W_{AB} = 0, \qquad W_{BC} = P\Delta V = nR\Delta T = -nRT_0$

$$W_{CA} = nRT\ell n\frac{V_f}{V_i} = nR(2T_0)\ell n2$$

$$Q_{BC} = nC_p\Delta T = \left(\frac{nR\gamma}{\gamma-1}\right)T_0$$

Efficiency, $$\eta = \frac{W}{Q} = \left[\frac{2\ell n2 - 1}{\gamma/(\gamma-1)}\right]$$

7. (c) $T_1 = 273 + 27 = 300\text{K}$

$T_2 = 273 + 927 = 1200\text{K}$

For adiabatic process,

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

$\Rightarrow P_1^{1-\gamma}\,T_1^{\gamma} = P_2^{1-\gamma}\,T_2^{\gamma}$

$$\Rightarrow \left(\frac{P_2}{P_1}\right)^{1-\gamma} = \left(\frac{T_1}{T_2}\right)^{\gamma} \quad \Rightarrow \left(\frac{P_1}{P_2}\right)^{1-\gamma} = \left(\frac{T_2}{T_1}\right)^{\gamma}$$

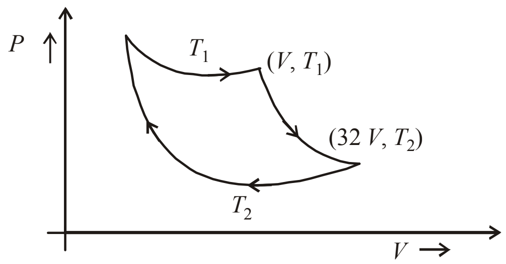
$$\left(\frac{P_1}{P_2}\right)^{1-1.4} = \left(\frac{1200}{300}\right)^{1.4} \quad \Rightarrow \left(\frac{P_1}{P_2}\right)^{-0.4} = (4)^{1.4}$$

$$\left(\frac{P_2}{P_1}\right)^{0.4} = 4^{1.4}$$

$$P_2 = P_1\,4^{\left(\frac{1.4}{0.4}\right)} = P_1\,4^{\left(\frac{7}{2}\right)}$$

$$= P_1\,(2^7) = 2 \times 128 = 256 \text{ atm}$$

8. (b)



We have, $TV^{\gamma-1}$ = constant

$\Rightarrow T_1V^{\gamma-1} = T_2(32V)^{\gamma-1}$

$\Rightarrow T_1 = (32)^{\gamma-1}.T_2$

For diatomic gas, $\gamma = \frac{7}{5}$

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

$\therefore T_1 = (32)^{\frac{2}{5}}.T_2 \Rightarrow T_1 = 4T_2$

Now, efficiency $= 1 - \frac{T_2}{T_1}$

$= 1 - \frac{T_2}{4T_2} = 1 - \frac{1}{4} = \frac{3}{4} = 0.75.$

9. (d) Isobaric compression is represented by curve AO
Work done = area under AD
$= 2 \times 10^2 \times (3-1)$
$= 4 \times 10^2 = 400$ J.

10. (a) As $P \propto \frac{1}{V^{1.5}}$, So $PV^{1.5}$ = constant

$\therefore \gamma = 1.5$ ($\because$ Process is adiabatic)

As we know, $\frac{C_p}{C_v} = \gamma \qquad \therefore \frac{C_p}{C_v} = 1.5$

11. (a) $W = \frac{nR\Delta T}{1-\gamma} \Rightarrow -146000 = \frac{1000 \times 8.3 \times 7}{1-\gamma}$

or $1 - \gamma = -\frac{58.1}{146} \Rightarrow \gamma = 1 + \frac{58.1}{146} = 1.4$

Hence the gas is diatomic.

12. (a) As, $P = \frac{1}{3}\left(\frac{U}{V}\right)$

But $\frac{U}{V} = KT^4$

So, $P = \frac{1}{3}KT^4$

or $\frac{uRT}{V} = \frac{1}{3}KT^4$ [As PV = u RT]

$\frac{4}{3}\pi R^3 T^3$ = constant

Therefore, $T \propto \frac{1}{R}$

13. (c) Heat required to change the temperature of vessel by a small amount dT

$-dQ = mCdT$

Total heat required

$$-Q = m\int_{20}^{4} 32\left(\frac{T}{400}\right)^3 dT = \frac{100 \times 10^{-3} \times 32}{(400)^3}\left[\frac{T^4}{4}\right]_{20}^{4}$$

$\Rightarrow Q = 0.001996$ kJ

Work done required to maintain the temperature of sink to T_2

$$W = Q_1 - Q_2 = \frac{Q_1 - Q_2}{Q_2}Q_2 = \left(\frac{T_1}{T_2} - 1\right)Q_2$$

$$\Rightarrow W = \left(\frac{T_1 - T_2}{T_2}\right)Q_2$$

For $T_2 = 20$ K

$W_1 = \frac{300-20}{20} \times 0.001996 = 0.028$ kJ

For $T_2 = 4$ K

$W_2 = \frac{300-4}{4} \times 0.001996 = 0.148$ kJ

As temperature is changing from 20k to 4 k, work done required will be more than W_1 but less than W_2.

14. (a) Initially
$V_1 = 5.6\ell$, $T_1 = 273$K, $P_1 = 1$ atm,

$\gamma = \frac{5}{3}$ (For monatomic gas)

The number of moles of gas is

$$n = \frac{5.6\ell}{22.4\ell} = \frac{1}{4}$$

Finally (after adiabatic compression)
$V_2 = 0.7\ell$
For adiabatic compression

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$\therefore T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1\left(\frac{5.6}{0.7}\right)^{\frac{5}{3}-1}$$

$$= T_1(8)^{2/3} = 4T_1$$

We know that work done in adiabatic process is

$$W = \frac{nR\Delta T}{\gamma - 1} = \frac{9}{8}RT_1$$

15. (c) Curve A, B shows expansion. For expansion of a gas,
$W_{isothermal} > W_{adiabatic}$
$P_{isothermal} > P_{adiabatic}$
$T_{isothermal} > T_{adiabatic}$
$\Rightarrow$ Slope of curve for isothermal change < slope of curve for adiabatic change.
So, curve B shows isothermal change and curve A shows adiabatic change.

16. (a) $PV^{3/2} = K, \qquad \log P + \frac{3}{2}\log V = \log K$

$$\frac{\Delta P}{P} + \frac{3}{2}\frac{\Delta V}{V} = 0$$

$$\frac{\Delta V}{V} = -\frac{2}{3}\frac{\Delta P}{P} \quad \text{or} \quad \frac{\Delta V}{V} = \left(-\frac{2}{3}\right)\left(\frac{2}{3}\right) = -\frac{4}{9}$$

17. (a) Initially the efficiency of the engine was $\frac{1}{6}$ which increases to $\frac{1}{3}$ when the sink temperature reduces by 62° C.

$\eta = \frac{1}{6} = 1 - \frac{T_2}{T_1}$, when T_2 = sink temperature

T_1 = source temperature

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

Secondly,

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

or, $T_1 = 62 \times 6 = 372K = 372 - 273 = 99°C$

& $T_2 = \frac{5}{6} \times 372 = 310K = 310 - 273 = 37°C$

18. **(b)** For an adiabatic process, the temperature-volume relationship is

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1} \Rightarrow T_1 = T_2\left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

Here $\gamma = 1.4$ (for diatomic gas). $V_2 = \frac{V_1}{32}, T_1 = T_i, T_2 = aT_i$

$\therefore T_i = aT_i\left[\frac{1}{32}\right]^{1.4-1}$ $\therefore T_i = aT_i\left[\frac{1}{2^5}\right]^{0.4} = \frac{aT_i}{4}$

$\therefore$ a = 4

19. **(b)** In the first-case adiabatic change,

$\Delta Q = 0, \Delta W = -35$ J

From 1st law of thermodynamics,

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

or $0 = \Delta U - 35$

$\therefore \Delta U = 35$ J

In the second case

$\Delta Q = 12$ cal $= 12 \times 4.2$ J $= 50.4$ J

$\Delta W = \Delta Q - \Delta U = 50.4 - 35 = 15.4$ J

20. **(a)** For an adiabatic change PV^γ = constant

$P_1V_1^\gamma = P_2V_2^\gamma$

As molar specific heat of gas at constant volume

$$C_v = \frac{3}{2}R$$

$$C_P = C_V + R = \frac{3}{2}R + R = \frac{5}{2}R;$$

$$\gamma = \frac{C_P}{C_V} = \frac{(5/2)R}{(3/2)R} = \frac{5}{3}$$

$\therefore$ From eq^n. (1)

$$P_2 = \left(\frac{V_1}{V_2}\right)^\gamma P_1 = \left(\frac{6}{2}\right)^{5/3} \times 10^5 \text{ N/m}^2$$

$= (3)^{5/3} \times 10^5 = 6.19 \times 10^5$ N/m^2

Work done

$$= \frac{1}{1-(5/3)}[6.19 \times 10^5 \times 2 \times 10^{-3} - 10^{-5} \times 6 \times 10^{-3}]$$

$$= -\left[\frac{2 \times 10^2 \times 3}{2}(6.19 - 3)\right]$$

$= -3 \times 10^2 \times 3.19 = -957$ joules

[–ve sign shows external work done on the gas]

21. **(b)** Efficiency of Carnot engine, $\eta = 1 - \frac{T_2}{T_1}$

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

$$\therefore \frac{T_2}{T_1} = 1 - \eta = 1 - \frac{40}{100} = \frac{60}{100} = \frac{3}{5} \quad (\because \eta = 40\%)$$

$$T_2 = \frac{3}{5}T_1 = \frac{3}{5} \times 500 \text{ K} = 300 \text{ K} \quad ...(i)$$

$(\because T_1 = 500\text{ K})$

Let T_1' be the temperature of the source for the same sink temperature when efficiency $\eta' = 50\%$

$$\therefore \frac{T_2}{T_1'} = 1 - \eta' = 1 - \frac{50}{100} = \frac{1}{2}$$

$T_1' = 2T_2 = 2 \times 300$ K $= 600$ K (Using eq. (i))

22. **(b)** $dW = P\Delta V = 1.01 \times 10^5 [1671 - 1] \times 10^{-6}$ Joule

$= \frac{1.01 \times 167}{4.2}$ cal.

$= 40$ cal. nearly

$\Delta Q = mL = 1 \times 540$,

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

or $\Delta U = 540 - 40 = 500$ cal.

23. **(c)** The temperature remains unchanged therefore

$U_f = U_i$.

Also, $\Delta Q = \Delta W$.

In the first step which is isochoric, $\Delta W = 0$.

In second step, pressure $= \frac{P}{n}$. Volume V is increased from V to nV.

$$\therefore \quad W = \frac{P}{n}(nV - V)$$

$$= PV\left(\frac{n-1}{n}\right)$$

$$= RT(1 - n^{-1})$$

24. **(b)** Efficiency of carnot engine

$n = 1 - \frac{T_2}{T_1}$ i.e., $\frac{1}{10} = 1 - \frac{T_2}{T_1}$

$\Rightarrow \frac{T_2}{T_1} = 1 - \frac{1}{10} = \frac{9}{10} \Rightarrow \frac{T_1}{T_2} = \frac{10}{9}$

$\therefore \quad w = Q_2\left(\frac{T_1}{T_2} - 1\right)$

i.e., $10 = Q_2\left(\frac{10}{9} - 1\right)$ $10 = Q_2\left(\frac{1}{9}\right)$

$\Rightarrow Q_2 = 90$J

So, 90 J heat is absorbed at lower temperature.

25. (a) $V_1 = 1\ell = 1000\ cm^3$, $P_1 = 72$ cm of Hg.
$V_2 = 900\ cm^3$, $P_2 = ?$
$\because$ The process is isothermal
$\therefore P_1V_1 = P_2V_2$
$72 \times 1000 = P_2 \times 900$
$P_2 = 80$ cm of Hg
$\therefore$ Stress $= P_2 - P_1 = 80 - 72 = 8$ cm of Hg.

26. (a) Process A $\to$ B occurs at constant pressure Hence work done in this process is

$$W_{AB} = PdV = P(V_2 - V_1)$$
$$= 10 \times (2-1) = 10\text{ J}$$

Process B $\to$ C, occurs at constant volume.

Hence, $W_{BC} = 0$

Given : Q = 5 J therefore, total work done is $W_1 = 5J$

($\because \Delta U = 0$ in a cyclic process)

Therefore, we have

$W_1 = W_{AB} + W_{BC} + W_{CA}$

or $5J = 10J + 0 + W_{CA}$

$\therefore W_{CA} = -5$ joule

27. (d) We know that in adiabatic process,
PV^γ = constant ....(1)
From ideal gas equation, we know that
$PV = nRT$

$$V = \frac{nRT}{P} \quad ....(2)$$

Puttingt the value from equation (2) in equation (1),

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

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

28. (b) According to first law of thermodynamics,
$\Delta Q = \Delta U + \Delta W$
ΔQ = heat absorbed by gas
ΔW = work done by gas.
$-20J = \Delta U - 8J$
$\Delta U = -12J = U_{Final} - U_{initial}$
$U_{initial} = 30J.$
$U_{Final} = 30 - 12 = 18J.$

29. (d) Coefficient of performance,

$$Cop = \frac{T_2}{T_1 - T_2}$$

$$5 = \frac{273-20}{T_1 - (273-20)} = \frac{253}{T_1 - 253}$$

$5T_1 - (5 \times 253) = 253$
$5T_1 = 253 + (5 \times 253) = 1518$

$$\therefore T_1 = \frac{1518}{5} = 303.6$$

or, $T_1 = 303.6 - 273 = 30.6 \cong 31°C$

30. (a) $W = \dfrac{nRdT}{\gamma - 1}$ γ is minimum for a polyatomic gas

Hence, W is greatest for polyatomic gas

31. (b) Heat is extracted from the source in path DA and AB is

$$\Delta Q = \frac{3}{2}R\left(\frac{P_0V_0}{R}\right) + \frac{5}{2}R\left(\frac{2P_0V_0}{R}\right)$$

$$\Rightarrow \frac{3}{2}P_0V_0 + \frac{5}{2}2P_0V_0 = \left(\frac{13}{2}\right)P_0V_0$$

32. (d) Isochoric proceess $dV = 0$

$W = 0$ processs 1

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

Adiabatic $|W| = \dfrac{nR\Delta T}{\gamma - 1}$ $\quad 0 < \gamma - 1 < 1$

As workdone in case of adiabatic process is more so process 3 is adiabatic and process 2 is isobaric

33. (c) For adiabatic process, $dU = -100$ J

which remains same for other processes also.

Let C be the heat capacity of 2nd process then

$-(C)5 = dU + dW$

$= -100 + 25 = -75$

$\therefore C = 15$ J/K

34. (c) Coefficient of performance of a refrigerator,

$$\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2} \quad \text{(Where } Q_2 \text{ is heat removed)}$$

Given: $T_2 = 4°C = 4 + 273 = 277$ k
$T_1 = 30°C = 30 + 273 = 303$ k

$$\therefore \beta = \frac{600 \times 4.2}{W} = \frac{277}{303 - 277}$$

$\Rightarrow W = 236.5$ joule

Power $P = \dfrac{W}{t} = \dfrac{236.5\text{ joule}}{1\text{ sec}} = 236.5$ watt.

35. (d) $dU = dQ - dW = (8 \times 10^5 - 6.5 \times 10^5) = 1.5 \times 10^5$ J

$dW = dQ - dU == 10^5 - 1.5 \times 10^5 = -0.5 \times 10^5\ J$

– ve sign indicates that work done on the gas is 0.5×10^5 J.

36. (d) In cyclic process, change in total internal energy is zero.

$\Delta U_{cyclic} = 0$

$$\Delta U_{BC} = nC_v\Delta T = 1 \times \frac{5R}{2}\Delta T$$

Where, C_v = molar specific heat at constant volume.
For BC, $\Delta T = -200$ K
$\therefore \quad \Delta U_{BC} = -500R$

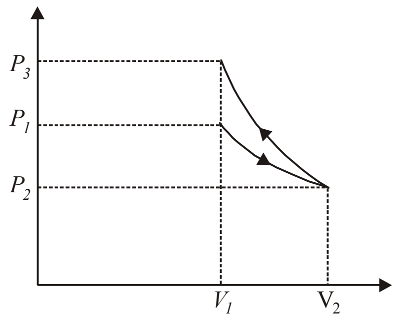
37. **(d)** Efficiency of engine A, $\eta_1 = 1 - \dfrac{T}{T_1}$,

Efficiency of engine B, $\eta_2 = 1 - \dfrac{T_2}{T}$

Here, $\eta_1 = \eta_2$

$\therefore \dfrac{T}{T_1} = \dfrac{T_2}{T} \Rightarrow T = \sqrt{T_1 T_2}$

38. **(b)** In the first process W is + ve as ΔV is positive, in the second process W is – ve as ΔV is – ve and area under the curve of second process is more
$\therefore$ Net Work < 0 and also $P_3 > P_1$.



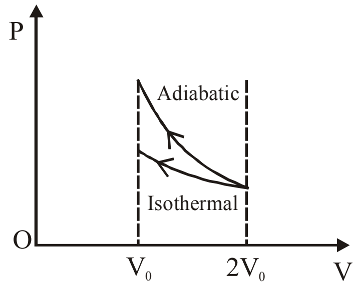
39. **(b)** Internal energy and entropy are state function, they do not depend upon path but on the state.

40. **(d)** 1st process is isothermal expansion which is only correct shown in option (d)
2nd process is isobaric compression which is correctly shown in option (d)

41. **(c)** $P_1 V_1^\gamma = P_2 V_2^\gamma$ (Adiabatic change)

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^\gamma = P_1 \left(\frac{V_1}{V_1/3}\right)^\gamma = P_2(3)^\gamma$$

42. **(b)** W_{ext} = negative of area with volume-axis
W(adiabatic) > W(isothermal)



43. **(a)** Initial and final condition is same for all process
$\Delta U_1 = \Delta U_2 = \Delta U_3$
from first law of thermodynamics
$\Delta Q = \Delta U + \Delta W$
Work done
$\Delta W_1 > \Delta W_2 > \Delta W_3$ (Area of P.V. graph)
So $\Delta Q_1 > \Delta Q_2 > \Delta Q_3$

44. **(c)** $W = \dfrac{\pi r_1 r_2}{2} = \dfrac{\pi \times 1 \times 1}{2}$
$= \pi/2$ J

45. **(b)** Differentiate PV = constant w.r.t V

$$\Rightarrow P\Delta V + V\Delta P = 0 \Rightarrow \frac{\Delta P}{P} = -\frac{\Delta V}{V}$$