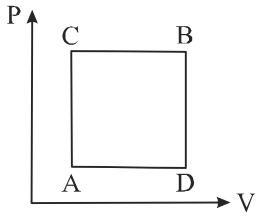
11

Thermodynamics

TOPIC 1 First Law of Thermodynamics

1. A gas can be taken from A to B via two different processes ACB and ADB.



When path ACB is used 60 J of heat flows into the system and 30J of work is done by the system. If path ADB is used work done by the system is 10 J. The heat Flow into the system in path ADB is : **[9 Jan. 2019 I]**

(a) 40 J (b) 80 J (c) 100 J (d) 20 J

2. 200g water is heated from 40°C to 60°C. Ignoring the slight expansion of water, the change in its internal energy is close to (Given specific heat of water = 4184 J/kgK): **[Online April 9, 2016]**

(a) 167.4 kJ (b) 8.4 kJ (c) 4.2 kJ (d) 16.7 kJ

3. A gas is compressed from a volume of $2m^3$ to a volume of $1m^3$ at a constant pressure of $100\ N/m^2$. Then it is heated at constant volume by supplying 150 J of energy. As a result, the internal energy of the gas: **[Online April 19, 2014]**

(a) increases by 250 J (b) decreases by 250 J

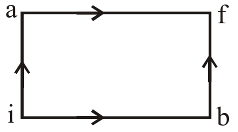
(c) increases by 50 J (d) decreases by 50 J

4. An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V_1 and contains ideal gas at pressure P_1 and temperature T_1. The other chamber has volume V_2 and contains ideal gas at pressure P_2 and temperature T_2. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be **[2008]**

(a) $\dfrac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$ (b) $\dfrac{P_1V_1T_1+P_2V_2T_2}{P_1V_1+P_2V_2}$

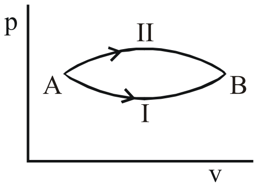
(c) $\dfrac{P_1V_1T_2+P_2V_2T_1}{P_1V_1+P_2V_2}$ (d) $\dfrac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_1+P_2V_2T_2}$

5. When a system is taken from state i to state *f* along the path iaf, it is found that $Q = 50$ cal and $W = 20$ cal. Along the path ibf $Q = 36$ cal. W along the path ibf is **[2007]**



(a) 14 cal (b) 6 cal (c) 16 cal (d) 66 cal

6. A system goes from *A* to *B* via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then **[2005]**



(a) relation between ΔU_1 and ΔU_2 can not be determined

(b) $\Delta U_1 = \Delta U_2$

(c) $\Delta U_2 < \Delta U_1$

(d) $\Delta U_2 > \Delta U_1$

7. Which of the following is incorrect regarding the first law of thermodynamics? **[2005]**

(a) It is a restatement of the principle of conservation of energy

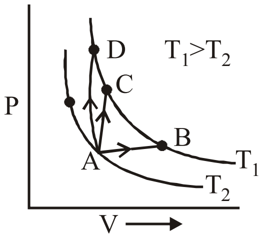
(b) It is not applicable to any cyclic process

(c) It does not introduces the concept of the entropy

(d) It introduces the concept of the internal energy

TOPIC 2 Specific Heat Capacity and Thermodynamical Processes

8. Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are lebelled as A → B, A → C and A → D. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the workdone as W_{AB}, W_{AC} and W_{AD}. The correct relation between these parameters are : **[5 Sep. 2020 (I)]**



(a) $E_{AB} = E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$
(b) $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} > 0$
(c) $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$
(d) $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$

9. In an adiabatic process, the density of a diatomic gas becomes 32 times its initial value. The final pressure of the gas is found to be *n* times the initial pressure. The value of *n* is : **[5 Sep. 2020 (II)]**

(a) 32 (b) 326 (c) 128 (d) $\frac{1}{32}$

10. Match the thermodynamic processes taking place in a system with the correct conditions. In the table : ΔQ is the heat supplied, ΔW is the work done and ΔU is change in internal energy of the system. **[4 Sep. 2020 (II)]**

Process	**Condition**
(I) Adiabatic	(A) $\Delta W = 0$
(II) Isothermal	(B) $\Delta Q = 0$
(III) Isochoric	(C) $\Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$
(IV) Isobaric	(D) $\Delta U = 0$

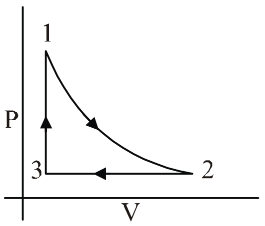
(a) (I)-(A), (II)-(B), (III)-(D), (IV)-(D)
(b) (I)-(B), (II)-(A), (III)-(D), (IV)-(C)
(c) (I)-(A), (II)-(A), (III)-(B), (IV)-(C)
(d) (I)-(B), (II)-(D), (III)-(A), (IV)-(C)

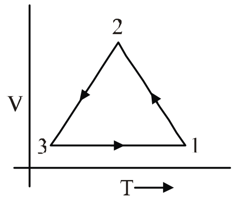
11. A balloon filled with helium (32°C and 1.7 atm.) bursts. Immediately afterwards the expansion of helium can be considered as : **[3 Sep. 2020 (I)]**

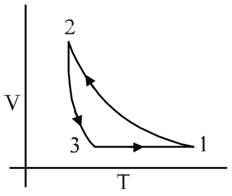
(a) irreversible isothermal (b) irreversible adiabatic
(c) reversible adiabatic (d) reversible isotherm7al

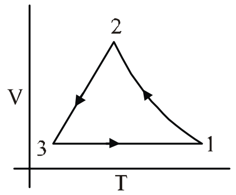
12. An engine takes in 5 mole of air at 20°C and 1 atm, and compresses it adiabaticaly to $1/10^{th}$ of the original volume. Assuming air to be a diatomic ideal gas made up of rigid molecules, the change in its internal energy during this process comes out to be *X* kJ. The value of *X* to the nearest integer is ________. **[NA 2 Sep. 2020 (I)]**

13. Which of the following is an equivalent cyclic process corresponding to the thermodynamic cyclic given in the figure?
where, $1 \rightarrow 2$ is adiabatic.
(Graphs are schematic and are not to scale) **[9 Jan. 2020 I]**



(a)


(b)


(c)


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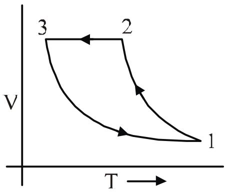
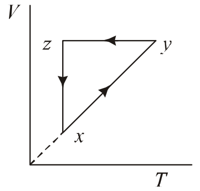
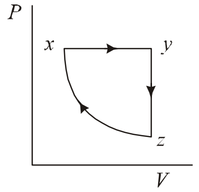


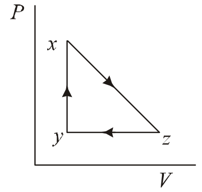
14. Starting at temperature 300 K, one mole of an ideal diatomic gas ($\gamma = 1.4$) is first compressed adiabatically from volume V_1 to $V_2 = \frac{V_1}{16}$. It is then allowed to expand isobarically to volume $2V_2$. If all the processes are the quasi-static then the final temperature of the gas (in °K) is (to the nearest integer) ______. **[9 Jan. 2020 II]**

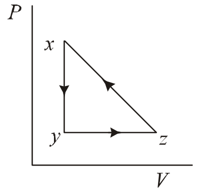
15. A thermodynamic cycle *xyzx* is shown on a *V-T* diagram.

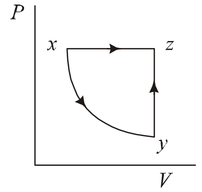


The *P-V* diagram that best describes this cycle is: (Diagrams are schematic and not to scale) **[8 Jan. 2020 I]**

(a)


(b)


(c)


(d)


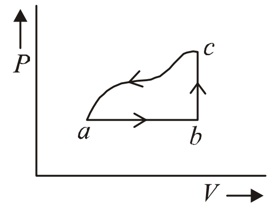
16. A litre of dry air at STP expands adiabatically to a volume of 3 litres. If $\gamma = 1.40$, the work done by air is: ($3^{1.4} = 4.6555$) [Take air to be an ideal gas] **[7 Jan. 2020 I]**

(a) 60.7 J (b) 90.5 J (c) 100.8 J (d) 48 J

17. Under an adiabatic process, the volume of an ideal gas gets doubled. Consequently the mean collision time between the gas molecule changes from τ_1 to τ_2. If $\frac{C_p}{C_v} = \gamma$ for this gas then a good estimate for $\frac{\tau_2}{\tau_1}$ is given by: **[7 Jan. 2020 I]**

(a) 2 (b) $\frac{1}{2}$ (c) $\left(\frac{1}{2}\right)^{\gamma}$ (d) $\left(\frac{1}{2}\right)^{\frac{\gamma+1}{2}}$

18. A sample of an ideal gas is taken through the cyclic process abca as shown in the figure. The change in the internal energy of the gas along the path ca is – 180 J, The gas absorbs 250 J of heat along the path ab and 60 J along the path bc. The work down by the gas along the path abc is: **[12 Apr. 2019 I]**



(a) 120 J (b) 130 J (c) 100 J (d) 140 J

19. A cylinder with fixed capacity of 67.2 lit contains helium gas at STP. The amount of heat needed to raise the temperature of the gas by 20°C is : [Given that R = 8.31 J mol^{-1} K^{-1}] **[10 Apr. 2019 I]**

(a) 350 J (b) 374 J (c) 748 J (d) 700 J

20. n moles of an ideal gas with constant volume heat capacity C_V undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is: **[10 Apr. 2019 I]**

(a) $\frac{nR}{C_V + nR}$ (b) $\frac{nR}{C_V - nR}$

(c) $\frac{4nR}{C_V - nR}$ (d) $\frac{4nR}{C_V + nR}$

21. One mole of an ideal gas passes through a process where pressure and volume obey the relation $P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$.

Here P_o and V_o are constants. Calculate the charge in the temperature of the gas if its volume changes from V_o to $2V_o$. **[10 Apr. 2019 II]**

(a) $\frac{1}{2}\frac{P_oV_o}{R}$ (b) $\frac{5}{4}\frac{P_oV_o}{R}$ (c) $\frac{3}{4}\frac{P_oV_o}{R}$ (d) $\frac{1}{4}\frac{P_oV_o}{R}$

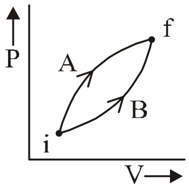
22. Following figure shows two processes A and B for a gas. If ΔQ_A and ΔQ_B are the amount of heat absorbed by the system in two cases, and ΔU_A and ΔU_B are changes in internal energies, respectively, then: **[9 April 2019 I]**

(a) $\Delta Q_A < \Delta Q_B, \Delta U_A < \Delta U_B$

(b) $\Delta Q_A > \Delta Q_B, \Delta U_A > \Delta U_B$

(c) $\Delta Q_A > \Delta Q_B, \Delta U_A = \Delta U_B$

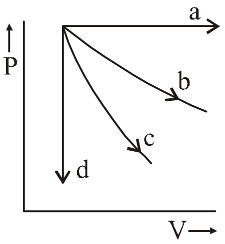
(d) $\Delta Q_A = \Delta Q_B; \Delta U_A = \Delta U_B$



23. A thermally insulted vessel contains 150 g of water at 0°C. Then the air from the vessel is pumped out adiabatically. A fraction of water turns into ice and the rest evaporates at 0°C itself. The mass of evaporated water will be closed to: (Latent heat of vaporization of water = 2.10×10^6 J kg^{-1} and Latent heat of Fusion of water = 3.36×10^5 J kg^{-1}) **[8 April 2019 I]**

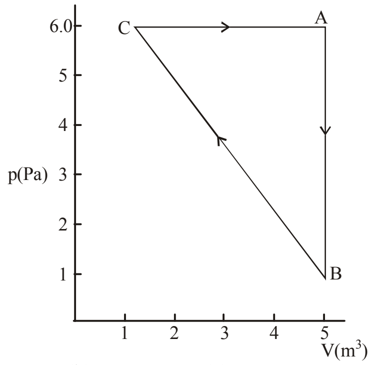
(a) 150 g (b) 20 g (c) 130 g (d) 35 g

24. The given diagram shows four processes *i.e.*, isochoric, isobaric, isothermal and adiabatic. The correct assignment of the processes, in the same order is given by : **[8 Apr. 2019 II]**



(a) a d b c (b) d a c b (c) a d c b (d) d a b c

25. For the given cyclic process CAB as shown for gas, the work done is: **[12 Jan. 2019 I]**



(a) 30 J (b) 10 J (c) 1 J (d) 5 J

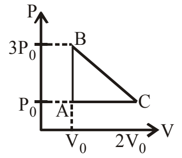
26. A rigid diatomic ideal gas undergoes an adiabatic process at room temperature. The relation between temperature and volume for this process is TV^x = constant, then x is: **[11 Jan. 2019 I]**

(a) $\frac{3}{5}$ (b) $\frac{2}{5}$ (c) $\frac{2}{3}$ (d) $\frac{5}{3}$

27. Half mole of an ideal monoatomic gas is heated at constant pressure of 1 atm from 20°C to 90°C. Work done by gas is close to: (Gas constant R = 8.31 J/mol-K) **[10 Jan. 2019 II]**

(a) 581 J (b) 291 J (c) 146 J (d) 73 J

28. One mole of an ideal monoatomic gas is taken along the path ABCA as shown in the PV diagram. The maximum temperature attained by the gas along the path BC is given by **[Online April 16, 2018]**



(a) $\frac{25}{8}\frac{P_0V_0}{R}$ (b) $\frac{25}{4}\frac{P_0V_0}{R}$ (c) $\frac{25}{16}\frac{P_0V_0}{R}$ (d) $\frac{5}{8}\frac{P_0V_0}{R}$

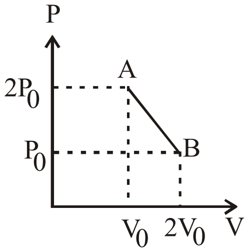
29. One mole of an ideal monoatomic gas is compressed isothermally in a rigid vessel to double its pressure at room temperature, 27°C. The work done on the gas will be:

[Online April 15, 2018]

(a) 300R ln 6 (b) 300R

(c) 300R ln 7 (d) 300R ln 2

30. 'n' moles of an ideal gas undergoes a process A → B as shown in the figure. The maximum temperature of the gas during the process will be : **[2016]**



(a) $\frac{9P_0V_0}{2nR}$ (b) $\frac{9P_0V_0}{nR}$ (c) $\frac{9P_0V_0}{4nR}$ (d) $\frac{3P_0V_0}{2nR}$

31. The ratio of work done by an ideal monoatomic gas to the heat supplied to it in an isobaric process is :

[Online April 9, 2016]

(a) $\frac{2}{5}$ (b) $\frac{3}{2}$ (c) $\frac{3}{5}$ (d) $\frac{2}{3}$

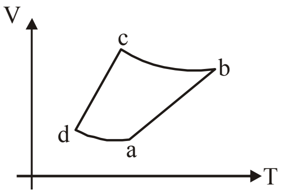
32. Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion, the average time of collision between molecules increases as V^q, where V is the volume of the gas. The value of q is : $\left(\gamma = \frac{C_p}{C_v}\right)$ **[2015]**

(a) $\frac{\gamma+1}{2}$ (b) $\frac{\gamma-1}{2}$ (c) $\frac{3\gamma+5}{6}$ (d) $\frac{3\gamma-5}{6}$

33. 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 : **[2015]**

(a) $T \propto \frac{1}{R}$ (b) $T \propto \frac{1}{R^3}$ (c) $T \propto e^{-R}$ (d) $T \propto e^{-3R}$

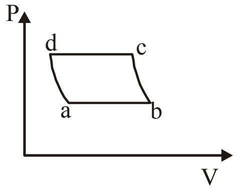
34. An ideal gas goes through a reversible cycle a→b→c→d has the V - T diagram shown below. Process d→a and b→c are adiabatic.



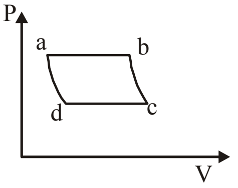
The corresponding P - V diagram for the process is (all figures are schematic and not drawn to scale) :

[Online April 10, 2015]

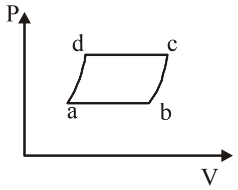
(a)



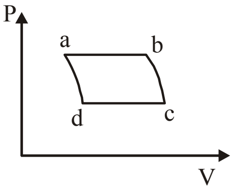
(b)



(c)

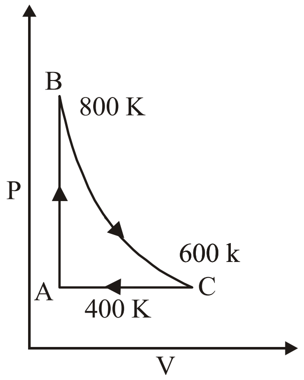


(d)



35. 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:

[2014]



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

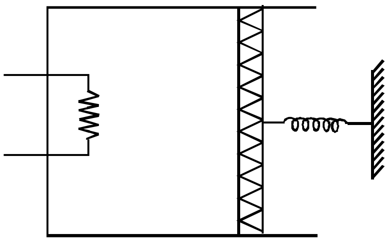
(b) The change in internal energy in the process CA is 700 R.

(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.

36. An ideal monoatomic gas is confined in a cylinder by a spring loaded piston of cross section 8.0×10^{-3} m^2. Initially the gas is at 300 K and occupies a volume of 2.4×10^{-3} m^3 and the spring is in its relaxed state as shown in figure. The gas is heated by a small heater until the piston moves out slowly by 0.1 m. The force constant of the spring is 8000 N/m and the atmospheric pressure is 1.0×10^5 N/m^2. The cylinder and the piston are thermally insulated. The piston and the spring are massless and there is no friction between the piston and the cylinder. The final temperature of the gas will be:

(Neglect the heat loss through the lead wires of the heater. The heat capacity of the heater coil is also negligible). **[Online April 11, 2014]**



(a) 300 K (b) 800 K (c) 500 K (d) 1000 K

37. During an adiabatic compression, 830 J of work is done on 2 moles of a diatomic ideal gas to reduce its volume by 50%. The change in its temperature is nearly:

($R = 8.3\ JK^{-1}\ mol^{-1}$) **[Online April 11, 2014]**

(a) 40 K (b) 33 K (c) 20 K (d) 14 K

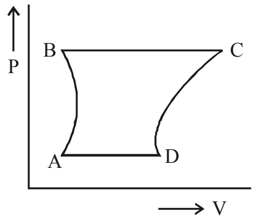
38. The equation of state for a gas is given by $PV = nRT + \alpha V$, where n is the number of moles and α is a positive constant. The initial temperature and pressure of one mole of the gas contained in a cylinder are T_o and P_o respectively. The work done by the gas when its temperature doubles isobarically will be: **[Online April 9, 2014]**

(a) $\frac{P_oT_oR}{P_o - \alpha}$ (b) $\frac{P_oT_oR}{P_o + \alpha}$

(c) $P_oT_oR \ln 2$ (d) P_oT_oR

39. A certain amount of gas is taken through a cyclic process (A B C D A) that has two isobars, one isochore and one isothermal. The cycle can be represented on a P-V indicator diagram as : **[Online April 22, 2013]**

(a)



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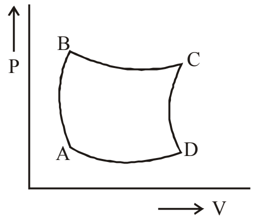

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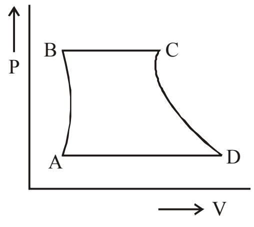

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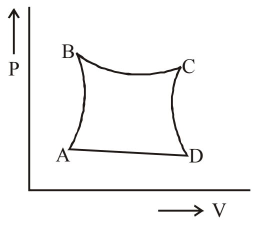
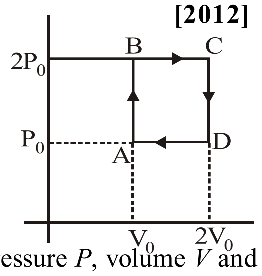


40. An ideal gas at atmospheric pressure is adiabatically compressed so that its density becomes 32 times of its initial value. If the final pressure of gas is 128 atmospheres, the value of 'γ' of the gas is : **[Online April 22, 2013]**

(a) 1.5 (b) 1.4 (c) 1.3 (d) 1.6

41. Helium gas goes through a cycle ABCDA (consisting of two isochoric and isobaric lines) as shown in figure. The efficiency of this cycle is nearly : (Assume the gas to be close to ideal gas) **[2012]**



(a) 15.4%

(b) 9.1%

(c) 10.5%

(d) 12.5%

42. An ideal monatomic gas with pressure P, volume V and temperature T is expanded isothermally to a volume $2V$ and a final pressure P_i. If the same gas is expanded adiabatically to a volume $2V$, the final pressure is P_a. The ratio $\frac{P_a}{P_i}$ is **[Online May 26, 2012]**

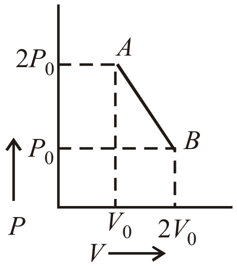
(a) $2^{-1/3}$ (b) $2^{1/3}$ (c) $2^{2/3}$ (d) $2^{-2/3}$

43. The pressure of an ideal gas varies with volume as $P = \alpha V$, where α is a constant. One mole of the gas is allowed to undergo expansion such that its volume becomes 'm' times its initial volume. The work done by the gas in the process is **[Online May 19, 2012]**

(a) $\frac{\alpha V}{2}\left(m^2 - 1\right)$ (b) $\frac{\alpha^2 V^2}{2}\left(m^2 - 1\right)$

(c) $\frac{\alpha}{2}\left(m^2 - 1\right)$ (d) $\frac{\alpha V^2}{2}\left(m^2 - 1\right)$

44. n moles of an ideal gas undergo a process $A \rightarrow B$ as shown in the figure. Maximum temperature of the gas during the process is **[Online May 12, 2012]**



(a) $\frac{9P_0V_0}{nR}$ (b) $\frac{3P_0V_0}{2nR}$ (c) $\frac{9P_0V_0}{2nR}$ (d) $\frac{9P_0V_0}{4nR}$

45. This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: In an adiabatic process, change in internal energy of a gas is equal to work done on/by the gas in the process.

Statement 2: The temperature of a gas remains constant in an adiabatic process. **[Online May 7, 2012]**

(a) Statement 1 is true, Statement 2 is true, Statement 2 is a correct explanation of Statement 1.

(b) Statement 1 is true, Statement 2 is false.

(c) Statement 1 is false, Statement 2 is true.

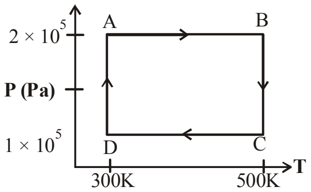
(d) Statement 1 is false, Statement 2 is true, Statement 2 is not a correct explanation of Statement 1.

46. A container with insulating walls is divided into equal parts by a partition fitted with a valve. One part is filled with an ideal gas at a pressure *P* and temperature *T*, whereas the other part is completly evacuated. If the valve is suddenly opened, the pressure and temperature of the gas will be : **[2011 RS]**

(a) $\frac{P}{2}, \frac{T}{2}$ (b) P, T (c) $P, \frac{T}{2}$ (d) $\frac{P}{2}, T$

Directions for questions 47 to 49: *Questions are based on the following paragraph.*

Two moles of helium gas are taken over the cycle *ABCDA*, as shown in the *P-T* diagram. **[2009]**



47. Assuming the gas to be ideal the work done on the gas in taking it from *A* to *B* is

(a) 300 R (b) 400 R (c) 500 R (d) 200 R

48. The work done on the gas in taking it from *D* to *A* is

(a) + 414 R (b) – 690 R (c) + 690 R (d) – 414 R

49. The net work done on the gas in the cycle *ABCDA* is

(a) 279 R (b) 1076 R (c) 1904 R (d) zero

50. 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 **[2006]** ($R = 8.3$ J mol^{-1} K^{-1})

(a) diatomic

(b) triatomic

(c) a mixture of monoatomic and diatomic

(d) monoatomic

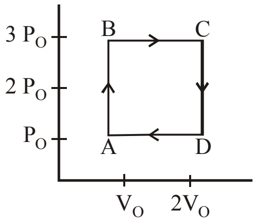
51. Which of the following parameters does not characterize the thermodynamic state of matter? **[2003]**

(a) Temperature (b) Pressure

(c) Work (d) Volume

TOPIC 3 Carnot Engine, Refrigerators and Second Law of Thermodynamics

52. An engine operates by taking a monatomic ideal gas through the cycle shown in the figure. The percentage efficiency of the engine is close is ______. **[NA 6 Sep. 2020 (II)]**



53. If minimum possible work is done by a refrigerator in converting 100 grams of water at 0°C to ice, how much heat (in calories) is released to the surroundings at temperature 27°C (Latent heat of ice = 80 Cal/gram) to the nearest integer? **[NA 3 Sep. 2020 (II)]**

54. A heat engine is involved with exchange of heat of 1915 J, – 40 J, +125 J and – *Q* J, during one cycle achieving an efficiency of 50.0%. The value of *Q* is : **[2 Sep. 2020 (II)]**

(a) 640 J (b) 40 J (c) 980 J (d) 400 J

55. A Carnot engine having an efficiency of $\frac{1}{10}$ is being used as a refrigerator. If the work done on the refrigerator is 10 J, the amount of heat absorbed from the reservoir at lower temperature is: **[8 Jan. 2020 II]**

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

56. A Carnot engine operates between two reservoirs of temperatures 900 K and 300 K. The engine performs 1200 J of work per cycle. The heat energy (in J) delivered by the engine to the low temperature reservoir, in a cycle, is _______. **[NA 7 Jan. 2020 I]**

57. Two ideal Carnot engines operate in cascade (all heat given up by one engine is used by the other engine to produce work) between temperatures, T_1 and T_2. The temperature of the hot reservoir of the first engine is T_1 and the temperature of the cold reservoir of the second engine is T_2. T is temperature of the sink of first engine which is also the source for the second engine. How is *T* related to T_1 and T_2, if both the engines perform equal amount of work ? **[7 Jan. 2020 II]**

(a) $T = \frac{2T_1T_2}{T_1 + T_2}$ (b) $T = \frac{T_1 + T_2}{2}$

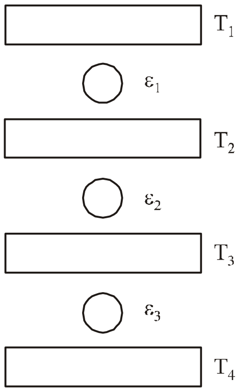
(c) $T = \sqrt{T_1T_2}$ (d) $T = 0$

58. A Carnot engine has an efficiency of 1/6. When the temperature of the sink is reduced by 62°C, its efficiency is doubled. The temperatures of the source and the sink are, respectively. **[12 Apr. 2019 II]**

(a) 62°C, 124°C (b) 99°C, 37°C

(c) 124°C, 62°C (d) 37°C, 99°C

59. Three Carnot engines operate in series between a heat source at a temperature T_1 and a heat sink at temperature T_4 (see figure). There are two other reservoirs at temperature T_2 and T_3, as shown, with $T_1 > T_2 > T_3 > T(4)$ The three engines are equally efficient if: **[10 Jan. 2019 I]**



(a) $T_2 = (T_1 T_4)^{1/2}; T_3 = (T_1^2 T_4)^{1/3}$

(b) $T_2 = (T_1^2 T_4)^{1/3}; T_3 = (T_1 T_4^2)^{1/3}$

(c) $T_2 = (T_1 T_4^2)^{1/3}; T_3 = (T_1^2 T_4)^{1/3}$

(d) $T_2 = (T_1^3 T_4)^{1/4}; T_3 = (T_1 T_4^3)^{1/4}$

60. Two Carnot engines A and B are operated in series. The first one, A receives heat at T_1 (= 600 K) and rejects to a reservoir at temperature T_2. The second engine B receives heat rejected by the first engine and in turn, rejects to a heat reservoir at T_3 (= 400 K). Calculate the temperature T_2 if the work outputs of the two engines are equal: **[9 Jan. 2019 II]**

(a) 600 K (b) 400 K (c) 300 K (d) 500 K

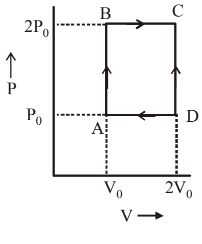
61. A Carnot's engine works as a refrigerator between 250 K and 300 K. It receives 500 cal heat from the reservoir at the lower temperature. The amount of work done in each cycle to operate the refrigerator is: **[Online April 15, 2018]**

(a) 420 J (b) 2100 J (c) 772 J (d) 2520 J

62. Two Carnot engines A and B are operated in series. Engine A receives heat from a reservoir at 600K and rejects heat to a reservoir at temperature T. Engine B receives heat rejected by engine A and in turn rejects it to a reservoir at 100K. If the efficiencies of the two engines A and B are represented by η_A and η_B respectively, then what is the value of $\frac{\eta_A}{\eta_B}$ **[Online April 15, 2018]**

(a) $\frac{12}{7}$ (b) $\frac{12}{5}$ (c) $\frac{5}{12}$ (d) $\frac{7}{12}$

63. An engine operates by taking n moles of an ideal gas through the cycle ABCDA shown in figure. The thermal efficiency of the engine is : (Take C_V =1.5 R, where R is gas constant) **[Online April 8, 2017]**



(a) 0.24

(b) 0.15

(c) 0.32

(d) 0.08

64. A Carnot freezer takes heat from water at 0°C inside it and rejects it to the room at a temperature of 27°C. The latent heat of ice is 336×10^3 J kg^{-1}. If 5 kg of water at 0°C is converted into ice at 0°C by the freezer, then the energy consumed by the freezer is close to : **[Online April 10, 2016]**

(a) 1.51×10^5 J (b) 1.68×10^6 J
(c) 1.71×10^7 J (d) 1.67×10^5 J

65. A solid body of constant heat capacity 1 J/°C is being heated by keeping it in contact with reservoirs in two ways : **[2015]**

(i) Sequentially keeping in contact with 2 reservoirs such that each reservoir supplies same amount of heat.

(ii) Sequentially keeping in contact with 8 reservoirs such that each reservoir supplies same amount of heat.

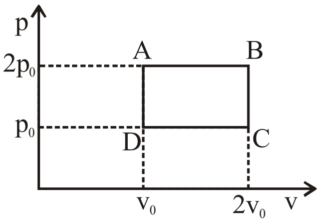
In both the cases body is brought from initial temperature 100°C to final temperature 200°C. Entropy change of the body in the two cases respectively is :

(a) *ln2, 2ln2* (b) *2ln2, 8ln2*
(c) *ln2, 4ln2* (d) *ln2, ln2*

66. A Carnot engine absorbs 1000 J of heat energy from a reservoir at 127°C and rejects 600 J of heat energy during each cycle. The efficiency of engine and temperature of sink will be: **[Online April 12, 2014]**

(a) 20% and – 43°C (b) 40% and – 33°C
(c) 50% and – 20°C (d) 70% and – 10°C

67.



The above p-v diagramrepresents 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 **[2013]**

(a) $p_0 v_0$ (b) $\left(\frac{13}{2}\right) p_0 v_0$

(c) $\left(\frac{11}{2}\right) p_0 v_0$ (d) $4 p_0 v_0$

68. A Carnot engine, whose efficiency is 40%, takes in heat from a source maintained at a temperature of 500K. It is desired to have an engine of efficiency 60%. Then, the intake temperature for the same exhaust (sink) temperature must be : **[2012]**

(a) efficiency of Carnot engine cannot be made larger than 50%
(b) 1200 K
(c) 750 K
(d) 600 K

69. The door of a working refrigerator is left open in a well insulated room. The temperature of air in the room will **[Online May 26, 2012]**

(a) decrease
(b) increase in winters and decrease in summers
(c) remain the same
(d) increase

70. This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: An inventor claims to have constructed an engine that has an efficiency of 30% when operated between the boiling and freezing points of water. This is not possible.

Statement 2: The efficiency of a real engine is always less than the efficiency of a Carnot engine operating between the same two temperatures.

[Online May 19, 2012]

(a) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.

(b) Statement 1 is true, Statement 2 is false.

(c) Statement 1 is false, Statement 2 is true.

(d) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.

71. A Carnot engine operating between temperatures T_1 and T_2 has efficiency $\frac{1}{6}$. When T_2 is lowered by 62 K its efficiency increases to $\frac{1}{3}$. Then T_1 and T_2 are, respectively: **[2011]**

(a) 372 K and 310 K (b) 330 K and 268 K

(c) 310 K and 248 K (d) 372 K and 310 K

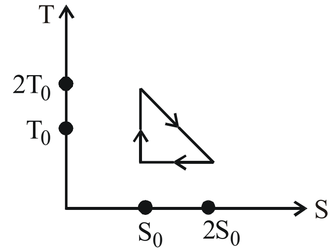
72. A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to 32 V, the efficiency of the engine is **[2010]**

(a) 0.5 (b) 0.75 (c) 0.99 (d) 0.25

73. 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 **[2007]**

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

74. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is **[2005]**



(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) $\frac{2}{3}$ (d) $\frac{1}{3}$

75. Which of the following statements is **correct** for any thermodynamic system ? **[2004]**

(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.

76. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of **[2003]**

(a) second law of thermodynamics

(b) conservation of momentum

(c) conservation of mass

(d) first law of thermodynamics

77. A Carnot engine takes 3×10^6 cal of heat from a reservoir at 627°C, and gives it to a sink at 27°C. The work done by the engine is **[2003]**

(a) 4.2×10^6 J (b) 8.4×10^6 J

(c) 16.8×10^6 J (d) zero

78. Which statement is incorrect? **[2002]**

(a) All reversible cycles have same efficiency

(b) Reversible cycle has more efficiency than an irreversible one

(c) Carnot cycle is a reversible one

(d) Carnot cycle has the maximum efficiency in all cycles

79. Even Carnot engine cannot give 100% efficiency because we cannot **[2002]**

(a) prevent radiation

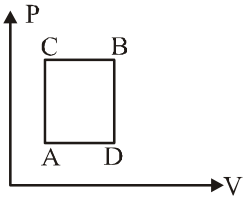
(b) find ideal sources

(c) reach absolute zero temperature

(d) eliminate friction

Hints & Solutions

1. **(a)**



ΔU remains same for both paths ACB and ADB

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

$\Rightarrow 60\text{ J} = 30\text{ J} + \Delta U_{ACB}$

$\Rightarrow U_{ACB} = 30\text{ J}$

$\therefore \Delta U_{ADB} = \Delta U_{ACB} = 30\text{ J}$

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

$= 10\text{ J} + 30\text{ J} = 40\text{ J}$

2. **(d)** Volume of water does not change, no work is done on or by the system (W = 0)

According to first law of thermodynamics

$$Q = \Delta U + W$$

For Isochoric process $Q = \Delta U$

$\Delta U = \mu c d T = 2 \times 4184 \times 20 = 16.7\text{ kJ}.$

3. **(a)** As we know,

$\Delta Q = \Delta u + \Delta w$ (Ist law of thermodynamics)

$\Rightarrow \Delta Q = \Delta u + P\Delta v$

or $150 = \Delta u + 100(1-2)$

$= \Delta u - 100$

$\therefore \quad \Delta u = 150 + 100 = 250\text{J}$

Thus the internal energy of the gas increases by 250 J

4. **(a)** Here $Q = 0$ and $W = 0$. Therefore from first law of thermodynamics $\Delta U = Q + W = 0$

Internal energy of first vessle + Internal energy of second vessel = Internal energy of combined vessel

$$n_1 C_v\, T_1 + n_2\, C_v\, T_2 = (n_1 + n_2) C_v\, T$$

$$\therefore\ T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

For first vessel $n_1 = \dfrac{P_1 V_1}{R T_1}$ and for second vessle

$$n_2 = \frac{P_2 V_2}{R T_2}$$

$$\therefore\ T = \frac{\dfrac{P_1 V_1}{R T_1} \times T_1 + \dfrac{P_2 V_2}{R T_2} \times T_2}{\dfrac{P_1 V_1}{R T_1} + \dfrac{P_2 V_2}{R T_2}}$$

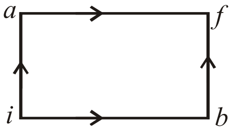
$$= \frac{T_1 T_2\ (P_1 V_1 + P_2 V_2)}{P_1 V_1 T_2 + P_2 V_2 T_1}$$

5. **(b)** For path *iaf*,

$Q_1 = 50$ cal, $W_1 = 20$ cal

By first law of thermodynamics,

$\Delta U = Q_1 - W_1 = 50 - 20 = 30$ cal.



For path *ibf*

$Q_2 = 36$ cal

$W_2 = ?$

$\Delta U_{ibf} = Q_2 - W_2$

Since, the change in internal energy does not depend on the path, therefore $\Delta U_{iaf} = \Delta U_{ibf}$

$\Delta U_{iaf} = \Delta U_{ibf}$

$\Rightarrow \quad 30 = Q_2 - W_2$

$\Rightarrow \quad W_2 = 36 - 30 = 6$ cal.

6. **(b)** Change in internal energy is independent of path taken by the process. It only depends on initial and final states *i.e.*,

$$\Delta U_1 = \Delta U_2$$

7. **(b, c)** First law is applicable to a cyclic process. Concept of entropy is introduced by the second law of thermodynamics.

8. **(b)** Temperature change ΔT is same for all three processes

$A \to B;\ A \to C$ and $A \to D$

$\Delta U = nC_v \Delta T$ = same

$E_{AB} = E_{AC} = E_{AD}$

Work done, $W = P \times \Delta V$

$AB \to$ volume is increasing $\Rightarrow W_{AB} > 0$

$AD \to$ volume is decreasing $\Rightarrow W_{AD} < 0$

$AC \to$ volume is constant $\Rightarrow W_{AC} = 0$

9. **(c)** In adiabatic process

PV^{γ} = constant

$\therefore P\left(\dfrac{m}{\rho}\right)^{\gamma}$ = constant $\quad \left(\because V = \dfrac{m}{\rho}\right)$

As mass is constant

$\therefore P \propto \rho^{\gamma}$

If P_i and P_f be the initial and final pressure of the gas and ρ_i and ρ_f be the initial and final density of the gas. Then

$$\frac{P_f}{P_i} = \left(\frac{\rho_f}{\rho_i}\right)^{\gamma} = (32)^{7/5}$$

$$\Rightarrow \frac{nP_i}{P_i} = (2^5)^{7/5} = 2^7$$

$\Rightarrow n = 2^7 = 128.$

10. **(d)**

(I) **Adiabatic process :** No exchange of heat takes place with surroundings.

$\Rightarrow \Delta Q = 0$

(II) **Isothermal process :** Temperature remains constant

$$\therefore \Delta T = 0 \Rightarrow \Delta U = \frac{f}{2} nR\Delta T \Rightarrow \Delta U = 0$$

No change in internal energy [$\Delta U = 0$].

(III) Isochoric process volume remains constant

$$\Delta V = 0 \Rightarrow W = \int P \cdot dV = 0$$

Hence work done is zero.

(IV) In isobaric process pressure remains constant.

$$W = P \cdot \Delta V \neq 0$$

$$\Delta U = \frac{f}{2} nR\Delta T = \frac{f}{2}[P\Delta V] \neq 0$$

$$\therefore \Delta Q = nC_p \Delta T \neq 0$$

11. **(b)** Bursting of helium balloon is irreversible and in this process $\Delta Q = 0$, so adiabatic.

12. **(46)**

For adiabatic process, $TV^{\gamma-1} =$ constant

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

$T_1 = 20°\text{C} + 273 = 293\text{ K}$, $V_2 = \frac{V_1}{10}$ and $\gamma = \frac{7}{5}$

$$T_1(V_1)^{\gamma-1} = T_2\left(\frac{V_1}{10}\right)^{\gamma-1}$$

$$\Rightarrow 293 = T_2\left(\frac{1}{10}\right)^{2/5} \Rightarrow T_2 = 293(10)^{2/5} \simeq 736\text{ K}$$

$$\Delta T = 736 - 293 = 443\text{ K}$$

During the process, change in internal energy

$$\Delta U = NC_V\Delta T = 5 \times \frac{5}{2} \times 8.3 \times 443 \simeq 46 \times 10^3\text{ J} = X\text{ kJ}$$

$$\therefore X = 46.$$

13. **(c)** For process 3 → 1 volume is constant

$\therefore$ Graph given in option (d) is wrong.

And process 1 → 2 is adiabatic $\therefore$ graph in option (1) is wrong

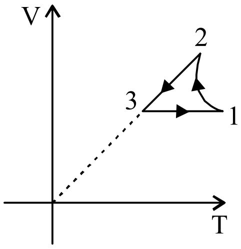
$\because$ v = constant

$P\uparrow, T\uparrow$

For Process 2 → 3 Pressure constant *i.e.*, P = constant

$\therefore$ $V\downarrow T\downarrow$

Hence graph (c) is the correct $V - T$ graph of given $P - V$ graph



14. **(1818)** For an adiabatic process,

$TV^{\gamma-1}$ = constant

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

$$\Rightarrow \; T_2 = (300) \times \left(\frac{V_1}{\frac{V_1}{16}}\right)^{1.4-1}$$

$\Rightarrow$ $T_2 = 300 \times (16)^{0.4}$

Ideal gas equation, $PV = nRT$

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

$\Rightarrow$ $V = kT$ (since pressure is constant for isobaric process)

So, during isobaric process

$V_2 = kT_2$ ...(i)

$2V_2 = kT_f$ ...(ii)

Dividing (i) by (ii)

$$\frac{1}{2} = \frac{T_2}{T_f}$$

$T_f = 2T_2 = 300 \times 2 \times (16)^{0.4} = 1818\,K$

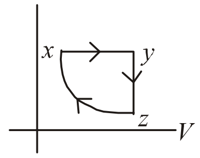
15. **(a)** From the corresponding V-T graph given in question,

Process xy → Isobaric expansion,

Process yz → Isochoric (Pressure decreases)

Process zx → Isothermal compression

Therefore, corresponding PV graph is as shown in figure



16. **(b)** Given, $V_1 = 1$ litre, $P_1 = 1$ atm

$V_2 = 3$ litre, $\gamma = 1.40$,

Using, PV^r = constant $\Rightarrow P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$$\Rightarrow P_2 = P_1 \times \left(\frac{1}{3}\right)^{1.4} = \frac{1}{4.6555}\,atm$$

$$\therefore \text{Work done, } W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{\left(1\times1 - \frac{1}{4.6555}\times3\right)1.01325\times10^5\times10^{-3}}{0.4} = 90.1\,J$$

Closest value of $W = 90.5\,J$

17. **(Bonus)** We know that Relaxation time,

$$T \propto \frac{V}{\sqrt{T}} \quad ...(i)$$

Equation of adiabatic process is

$TV^{\gamma-1}$ = constant

$$\Rightarrow \quad T \propto \frac{1}{V^{\gamma-1}}$$

$$\Rightarrow \quad T \propto V^{1+\frac{\gamma-1}{2}} \qquad \text{using (i)}$$

$$\Rightarrow \quad T \propto V^{\frac{1+\gamma}{2}}$$

$$\Rightarrow \quad \frac{T_f}{T_i} = \left(\frac{2V}{V}\right)^{\frac{1+\gamma}{2}} = (2)^{\frac{1+\gamma}{2}}$$

18. **(b)** $\Delta U_{ac} = -(\Delta U_{ca}) = -(-180) = 180$ J
$Q = 250 + 60 = 310$ J
Now $Q = \Delta U + W$
or $310 = 180 + W$
or $W = 130$ J

19. **(c)** As the process is isochoric so,

$$Q = nc_V\Delta T = \frac{67.2}{22.4} \times \frac{3R}{2} \times 20 = 90R = 90 \times 8.31 \simeq 748 \text{j.}$$

20. **(a)** At constant volume
Work done (W) = $nR\Delta T$
Heat given $Q = C_V\Delta T + nR\Delta T$

$$\text{So, } \therefore \frac{W}{Q} = \frac{nR\Delta T}{C_V\Delta T + nR\Delta T} = \frac{nR}{C_V + nR}$$

21. **(b)** We have given,

$$P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$$

When $V_1 = V_0$

$$\Rightarrow P_1 = P_0\left[1 - \frac{1}{2}\right] = \frac{P_0}{2}$$

When $V_2 = 2V_0$

$$\Rightarrow P_2 = P_0\left[1 - \frac{1}{2}\left(\frac{1}{4}\right)\right] = \left(\frac{7P_0}{8}\right)$$

$$\Delta T = T_2 - T_1 = \left|\frac{P_1V_1}{nR} - \frac{P_2V_2}{nR}\right| \quad \left[\because T = \frac{PV}{nR}\right]$$

$$\Delta T = \left|\left(\frac{1}{nR}\right)(P_1V_1 - P_2V_2)\right| = \left(\frac{1}{nR}\right)\left|\left(\frac{P_0V_0}{2} - \frac{7P_0V_0}{4}\right)\right|$$

$$= \frac{5P_0V_0}{4nR} = \frac{5P_0V_0}{4R} \qquad (\because n = 1)$$

22. **(c)** Internal energy depends only on initial and final state
So, $\Delta U_A = \Delta U_B$
Also $\Delta Q = \Delta U + W$
As $W_A > W_B \Rightarrow \Delta Q_A > \Delta Q_B$

23. **(b)** Suppose amount of water evaporated be M gram.
Then (150 – M) gram water converted into ice.
so, heat consumed in evoporation = Heat released in fusion
$M \times L_v = (150 - M) \times L_s$
$M \times 2.1 \times 10^6 = (150 - M) \times 3.36 \times 10^5$
$\Rightarrow M - 20$ g

24. **(d)** a → Isobasic, b → Isothermal, c → Adiabatic, d → Isochoric

25. **(b)** Total work done by the gas during the cycle is equal to area of triangle ABC.

$$\therefore \ \Delta W = \frac{1}{2} \times 4 \times 5 = 10 \text{ J}$$

26. **(b)** Equation of adiabatic change is
$TV^{\gamma-1}$ = constant

Put $\gamma = \frac{7}{5}$, we get: $\gamma - 1 = \frac{7}{5} - 1$

$$\therefore x = \frac{2}{5}$$

27. **(b)** Work done,

$$W = P\Delta V = nR\Delta T = \frac{1}{2} \times 8.31 \times 70 \simeq 291\text{J}$$

28. **(a)** Equation of the BC

$$P = P_0 - \frac{2P_0}{V_0}(V - 2V_0)$$

using PV = nRT

$$\text{Temperature, } T = \frac{P_0V - \frac{2P_0V^2}{V_0} + 4P_0V}{1 \times R}$$

$$(\because \ n = 1 \text{ mole given})$$

$$T = \frac{P_0}{F}\left[5V - \frac{2V^2}{V_0}\right]$$

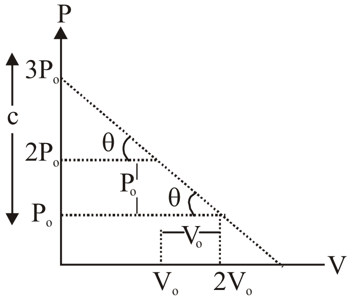
$$\frac{dT}{dV} = 0 \Rightarrow 5 - \frac{4V}{V_0} = 0 \Rightarrow V = \frac{5}{4}V_0$$

$$T = \frac{P_0}{R}\left[5 \times \frac{5V_0}{4} - \frac{2}{V_0} \times \frac{25}{16}V_0^2\right] = \frac{25}{8}\frac{P_0V_0}{R}$$

29. **(d)** Work done on gas = $nRT \ \ell n\left(\frac{p_f}{p_1}\right) = R(300) \ \ell n(2)$

$$= 300 \text{ Rln2} \ \left(\because \frac{P_f}{p_i} = 2 \text{ given}\right)$$

30. **(c)** The equation for the line is



$$P = \frac{-P_0}{V_0}V + 3P \qquad \left[\text{slope} = \frac{-P_0}{V_0}, \ c = 3P_0\right]$$

$PV_0 + P_0V = 3P_0V_0$ ...(i)
But $pV = nRT$

$$\therefore \ P = \frac{nRT}{V} \qquad \text{...(ii)}$$

$$\text{From (i) \& (ii) } \frac{nRT}{V}V_0 + P_0V = 3P_0V_0$$

From (i) & (ii) $\frac{nRT}{V}V_0 + P_0V = 3P_0V_0$

$\therefore$ nRT $V_0 + P_0V^2 = 3P_0V_0V$ ...(iii)

For temperature to be maximum $\frac{dT}{dV} = 0$

Differentiating e.q. (iii) by 'V' we get

$$nRV_0\frac{dT}{dV} + P_0(2V) = 3P_0V_0$$

$$\therefore nRV_0\frac{dT}{dV} = 3P_0V_0 - 2P_0V$$

$$\frac{dT}{dV} = \frac{3P_0V_0 - 2P_0V}{nRV_0} = 0$$

$$V = \frac{3V_0}{2} \quad \therefore \quad P = \frac{3P_0}{2} \quad \text{[From (i)]}$$

$$\therefore T_{max} = \frac{9P_0V_0}{4nR} \quad \text{[From (iii)]}$$

8. **(a)** Efficiency of heat engine is given by

$$\eta = \frac{w}{Q} = 1 - \frac{C_V}{C_P} = \frac{R}{C_p} = \frac{R}{\frac{5R}{2}} = \frac{2}{5}$$

($\because C_p - C_v = R$)

For monoatomic gas $C_P = \frac{5}{2}R$.

9. **(a)** $\tau = \frac{1}{\sqrt{2}\pi d^2\left(\frac{N}{V}\right)\sqrt{\frac{3RT}{M}}}$

$t\ \mu\ \frac{V}{\sqrt{T}}$

As, $TV^{\gamma-1} = K$

So, $\tau \propto V^{\gamma + 1/2}$

Therefore, $q = \frac{g+1}{2}$

10. **(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]

$\frac{4}{3}pR^3T^3$ = constant

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

11. **(b)** In *VT* graph

ab-process : Isobaric, temperature increases.

bc process : Adiabatic, pressure decreases.

cd process : Isobaric, volume decreases.

da process : Adiabatic, pressure increases.

The above processes correctly represented in *P-V* diagram (b).

12. **(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

$\therefore \quad \Delta U_{BC} = -500R$

13. **(c)**

14. **(c)** **Given :** work done, $W = 830$ J

No. of moles of gas, $\mu = 2$

For diatomic gas $\gamma = 1.4$

Work done during an adiabatic change

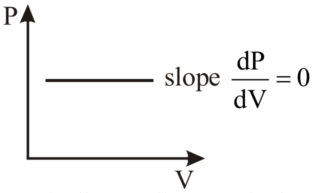
$$W = \frac{\mu R(T_1 - T_2)}{\gamma - 1}$$

$$\Rightarrow 830 = \frac{2 \times 8.3(\Delta T)}{1.4 - 1} = \frac{2 \times 8.3(\Delta T)}{0.4}$$

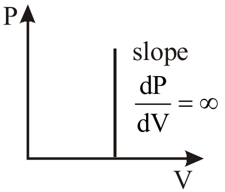
$$\Rightarrow \Delta T = \frac{830 \times 0.4}{2 \times 8.3} = 20 \text{ K}$$

15. **(a)**

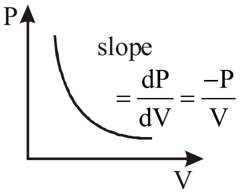
16. **(c)** P-V indicator diagram for isobaric



P-V indicator diagram for isochoric process



P-V indicator diagram for isothermal process



17. **(b)** Volume of the gas

$v = \frac{m}{d}$ and

Using PV^γ = constant

$$\frac{P'}{P} = \frac{V}{V'} = \left(\frac{d'}{d}\right)^\gamma$$

or $128 = (32)^\gamma$

$\therefore \gamma = \frac{7}{5} = 1.4$

18. **(a)** The efficiency

$$\eta = \frac{\text{output work}}{\text{heat given to the system}}$$

$$= n\frac{3}{2}R\Delta T \;= \frac{3}{2}V_0\Delta P \;= \frac{3}{2}\,P_0V_0$$

$$W_i = \frac{\mathrm{n}}{2}(P_0V_0) + \frac{n}{2}(2P_0V_0) + 2P_0V_0$$

Heat given in going B to $C = nCp\Delta T$

$$= n\left(\frac{5}{2}R\right)\Delta T \;= \frac{5}{2}(2P_0)\Delta V$$

$= 5P_0V_0$

and W_0 = area under PV diagram P_0V_0

$$\eta = \frac{W}{Q} = \frac{P_0V_0}{\frac{13}{2}P_0V_0} = \frac{2}{13}$$

Efficiency in %

$$\eta = \frac{2}{13}\times 100 = \frac{200}{13} \simeq 15.4\%$$

42. **(d)** For isothermal process :

$PV = P_i\,.\,2V$

$P = 2P_i$ ...(i)

For adiabatic process

$PV^{\gamma} = P_a\,(2V)^{\gamma}$

($\because$ for monatomic gas $\gamma = 5/3$)

or, $2P_iV^{\frac{5}{3}} = P_a(2V)^{\frac{5}{3}}$ [From (i)]

$$\Rightarrow\ \frac{P_a}{P_i} = \frac{2}{2^{\frac{5}{3}}}$$

$$\Rightarrow\ \frac{P_a}{P_i} = 2^{\frac{-2}{3}}$$

43. **(d)** Given $P = \alpha V$

Work done, $w = \int_V^{mV} PdV$

$$= \int_V^{mV} \alpha V dV \;=\; \frac{\alpha V^2}{2}(m^2 - 1).$$

44. **(b)** Work done during the process $A \to B$

= Area of trapezium (= area bounded by indicator diagram with V-axis)

$$= \frac{1}{2}\left(2P_0 + P_0\right)\left(2V_0 - V_0\right) = \frac{3}{2}P_0V_0$$

Ideal gas eqn : $PV = nRT$

$$\Rightarrow\quad T = \frac{PV}{nR} = \frac{3P_0V_0}{2nR}$$

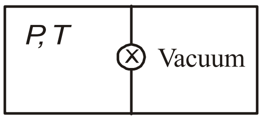
45. **(b)** In an adiabatic process, $\delta H = 0$

And according to first law of thermodynamics

$\delta H = \delta U + W$

$\therefore W = -\,\delta U$

46. **(d)**



It is the free expansion

$\therefore$ So, T remains constant

$\Rightarrow\ P_1V_1 = P_2V_2$

$$\Rightarrow\ P\frac{V}{2} = P_2\left(V\right)$$

$$P_2 = \left(\frac{P}{2}\right)$$

47. **(b)** The process $A \to B$ is isobaric.

$\therefore$ work done $W_{AB} = nR(T_2 - T_1)$

$= 2R(500 - 300) = 400R$

48. **(a)** The process D to A is isothermal as temperature is constant.

Work done, $W_{DA} = 2.303nRT\ \log_{10}\dfrac{P_D}{P_A}$

$= 2.303 \times 2\ R \times 300$

$\log_{10}\dfrac{1\times 10^5}{2\times 10^5} - 414\mathrm{R}.$

Therefore, work done on the gas is $+414\,R$.

49. **(a)** The net work in the cycle $ABCDA$ is

$$W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$$

$$= 400R + 2.303nRT\log\frac{P_B}{P_C} + (-400R) - 414R$$

$$= 2.303 \times 2R \times 500\log\frac{2\times 10^5}{1\times 10^5} - 414\,R$$

$= 693.2\,R - 414\,R \qquad = 279.2\,R$

50. **(a)** Work done in adiabatic compression is given by

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

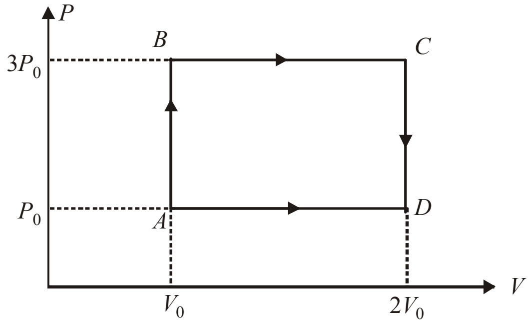
$$\Rightarrow\ -146000 = \frac{1000\times 8.3\times 7}{1-\gamma}$$

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

Hence the gas is diatomic.

51. **(c)** Work is not a state function. The remaining three parameters are state function.

52. **(19)**



From the figure,

Work, $W = 2P_0V_0$

Heat given, $Q_{\text{in}} = W_{AB} + W_{BC} = n \cdot C_V \Delta T_{AB} + nC_P \Delta T_{BC}$

$$= n\frac{3R}{2}(T_B - T_A) + \frac{n5R}{2}(T_C - T_B)$$

$$\left(\because C_v = \frac{3R}{2} \text{ and } C_P = \frac{5R}{2}\right)$$

$$= \frac{3}{2}(P_BV_B - P_AV_A) + \frac{5}{2}(P_CV_C - P_BV_B)$$

$$= \frac{3}{2} \times [3P_0V_0 - P_0V_0] + \frac{5}{2}[6P_0V_0 - 3P_0V_0]$$

$$= 3P_0V_0 + \frac{15}{2}P_0V_0 = \frac{21}{2}P_0V_0$$

Efficiency, $\eta = \dfrac{W}{Q_{\text{in}}} = \dfrac{2P_0V_0}{\frac{21}{2}P_0V_0} = \dfrac{4}{21}$

$\eta\% = \dfrac{400}{21} \approx 19.$

53. **(8791)**

Given,

Heat absorbed, $Q_2 = mL = 80 \times 100 = 8000$ Cal

Temperature of ice, $T_2 = 273$ K

Temperature of surrounding,

$T_1 = 273 + 27 = 300$ K

$$\text{Efficiency} = \frac{w}{Q_2} = \frac{Q_1 - Q_2}{Q_2} = \frac{T_1 - T_2}{T_2} = \frac{300 - 273}{273}$$

$$\Rightarrow \frac{Q_1 - 8000}{8000} = \frac{27}{273} \Rightarrow Q_1 = 8791 \text{ Cal}$$

54. **(c)** Efficiency, $\eta = \dfrac{\text{Work done}}{\text{Heat absorbed}} = \dfrac{W}{\Sigma Q}$

$$= \frac{Q_1 + Q_2 + Q_3 + Q_4}{Q_1 + Q_3} = 0.5$$

Here, $Q_1 = 1915$ J, $Q_2 = -40$ J and $Q_3 = 125$ J

$$\therefore \frac{1915 - 40 + 125 + Q_4}{1915 + 125} = 0.5$$

$$\Rightarrow 1915 - 40 + 125 + Q_4 = 1020$$

$$\Rightarrow Q_4 = 1020 - 2000$$

$$\Rightarrow Q_4 = -Q = -980 \text{ J}$$

$$\Rightarrow Q = 980 \text{ J}$$

55. **(d)** For carnot refrigerator

$$\text{Efficiency} = \frac{Q_1 - Q_2}{Q_1}$$

Where,

Q_1 = heat lost from sorrounding

Q_2 = heat absorbed from reservoir at low temperature.

Also, $\dfrac{Q_1 - Q_2}{Q_1} = \dfrac{w}{Q_1}$

$$\Rightarrow \frac{1}{10} = \frac{\text{w}}{\text{Q}_1}$$

$\Rightarrow Q_1 = w \times 10 = 100\,J$

So, $Q_1 - Q_2 = w$

$\Rightarrow Q_2 = Q_1 - w$

$\Rightarrow 100 - 10 = Q_2 = 90\,J$

56. **(600.00)** Given; $T_1 = 900\,K$, $T_2 = 300K$, $W = 1200\,J$

Using, $1 - \dfrac{T_2}{T_1} = \dfrac{W}{Q_1}$

$$\Rightarrow 1 - \frac{300}{900} = \frac{1200}{Q_1}$$

$$\Rightarrow \frac{2}{3} = \frac{1200}{Q_1} \Rightarrow Q_1 = 1800$$

Therefore heat energy delivered by the engine to the low temperature reservoir, $Q_2 = Q_1 - W = 1800 - 1200 = 600.00\,J$

57. **(b)** Let Q_H = Heat taken by first engine

Q_L = Heat rejected by first engine

Q_2 = Heat rejected by second engine

Work done by 1st engine = work done by 2nd engine

$W = Q_H - Q_L = Q_L - Q_2 \quad \Rightarrow 2Q_L = Q_H + Q_2$

$$2 = \frac{\theta_H}{\theta_L} + \frac{\theta_2}{\theta_L}$$

Let T be the temperature of cold reservoir of first engine. Then in carnot engine.

$$\frac{Q_H}{Q_L} = \frac{T_1}{T} \text{ and } \frac{Q_L}{Q_2} = \frac{T}{T_2}$$

$$\Rightarrow \quad 2 = \frac{T_1}{T} + \frac{T_2}{T} \qquad \text{using (i)}$$

$$\Rightarrow \quad 2T = T_1 + T_2 \quad \Rightarrow \quad T = \frac{T_1 + T_2}{2}$$

58. **(b)** Using, $n = 1 - \dfrac{T_2}{T_1}$

$$n = \frac{1}{6} = 1 - \frac{T_2}{T_1}$$

and $\dfrac{T}{3} = 1 - \dfrac{T_2 - 62}{T_1}$

On solving, we get

$T_1 = 99°\text{C}$ and $T_2 = 37°\text{C}$

59. **(b)** According to question, $\eta_1 = \eta_2 = \eta_3$

$$\therefore 1 - \frac{\text{T}_2}{\text{T}_1} = 1 - \frac{\text{T}_3}{\text{T}_2} = 1 - \frac{\text{T}_4}{\text{T}_3}$$

[$\because$ Three engines are equally efficient]

$$\Rightarrow \frac{T_2}{T_1}=\frac{T_3}{T_2}=\frac{T_4}{T_3}$$

$$\Rightarrow T_2=\sqrt{T_1T_3} \qquad ...(i)$$

$$T_3=\sqrt{T_2T_4} \qquad ...(ii)$$

From (i) and (ii)

$$T_2=(T_1^2T_4)^{1/3}$$

$$T_3=(T_1T_4^2)^{1/3}$$

60. **(d)** $\eta_A=\frac{T_1-T_2}{T_1}=\frac{w_A}{Q_1}$

and, $\eta_B=\frac{T_2-T_3}{T_2}=\frac{W_B}{Q_2}$

According to question,
$W_A=W_B$

$$\therefore \frac{Q_1}{Q_2}=\frac{T_1}{T_2}\times\frac{T_2-T_3}{T_1-T_2}=\frac{T_1}{T_2}$$

$$\therefore T_2=\frac{T_1+T_3}{2}$$

$$=\frac{600+400}{2}$$

$=500K$

61. **(a)** Given: Temperature of cold body, T_2 = 250 K temperature of hot body; T_1 = 300 K
Heat received, Q_2 = 500 cal work done, W = ?

$$\text{Efficiency}=1-\frac{T_2}{T_1}=\frac{W}{Q_2+W} \Rightarrow 1-\frac{250}{300}=\frac{W}{Q_2+W}$$

$$W=\frac{Q_2}{5}=\frac{500\times 4.2}{5}J=420\text{ J}$$

62. **(d)** Efficiency of engine *A*, $n_A=\frac{T_1-T_2}{T_1}$

and $n_B=\frac{T_2-T_3}{T_2}; T_2=\frac{T_1+T_3}{2}=350\,K$

$$\text{or} \quad \frac{n_A}{n_B}=\frac{\frac{600-350}{600}}{\frac{350-100}{350}}=\frac{7}{12}$$

63. **(b)** Work-done (W) = P_0V_0
According to principle of calorimetry
Heat given = $Q_{AB}=Q_{BC}$
$=nC_VdT_{AB}+nC_PdT_{BC}$

$$=\frac{3}{2}(nRT_B-nRT_A)+\frac{5}{2}(nRT_C-nRT_B)$$

$$=\frac{3}{2}(2P_0V_0-P_0V_0)+\frac{5}{2}(4P_0V_0-2P_0V)$$

$$=\frac{13}{2}P_0V_0$$

Thermal efficiency of engine $(\eta)=\frac{W}{Q_{given}}=\frac{2}{13}=0.15$

64. **(d)** $\Delta H=mL=5\times 336\times 10^3=Q_{sink}$

$$\frac{Q_{sink}}{Q_{source}}=\frac{T_{sink}}{T_{source}}$$

$$\therefore Q_{source}=\frac{T_{source}}{T_{sink}}\times Q_{sink}$$

Energy consumed by freezer

$$\therefore w_{output}=Q_{source}-Q_{sink}=Q_{sink}\left(\frac{T_{source}}{T_{sink}}-1\right)$$

Given: $T_{source}=27°C+273=300K,$

$T_{sink}=0°C+273=273\,k$

$$W_{output}=5\times 336\times 10^3\left(\frac{300}{273}-1\right)=1.67\times 10^5\text{ J}$$

65. **(d)** The entropy change of the body in the two cases is same as entropy is a state function.

66. **(b)** Given : $Q_1=1000$ J
$Q_2=600$ J
$T_1=127°C=400$ K
$T_2=?$
$\eta=?$

Efficiency of carnot engine,

$$\eta=\frac{W}{Q_1}\times 100\%$$

$$\text{or,} \quad \eta=\frac{Q_2-Q_1}{Q_1}\times 100\%$$

$$\text{or,} \quad \eta=\frac{1000-600}{1000}\times 100\%$$

$\eta=40\%$

Now, for carnot cycle $\frac{Q_2}{Q_1}=\frac{T_2}{T_1}$

$$\frac{600}{1000}=\frac{T_2}{400}$$

$$T_2=\frac{600\times 400}{1000}$$

$=240$ K
$=240-273$
$\therefore T_2=-33°C$

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

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

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

68. **(c)** The efficiency of the carnot's heat engine is given as

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

When efficiency is 40%,
$T_1 = 500$ K; $\eta = 40$

$$40 = \left(1 - \frac{T_2}{500}\right) \times 100$$

$$\Rightarrow \frac{40}{100} = 1 - \frac{T_2}{500}$$

$$\Rightarrow \frac{T_2}{500} = \frac{60}{100} \Rightarrow T_2 = 300 \text{ K}$$

When efficiency is 60%, then

$$\frac{60}{100} = \left(1 - \frac{300}{T_2}\right) \Rightarrow \frac{300}{T_2} = \frac{40}{100}$$

$$\Rightarrow T_2 = \frac{100 \times 300}{40} \quad \Rightarrow \quad T_2 = 750 \text{ K}$$

69. **(d)** In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber, therefore the room is heated. If the door of a refrigerator is kept open.

70. **(d)** According to Carnot's theorem - no heat engine working between two given temperatures of source and sink can be more efficient than a perfectly reversible engine i.e. Carnot engine working between the same two temperatures.

Efficiency of Carnot's engine, $n = 1 - \frac{T_2}{T_1}$

where, T_1 = temperature of source
T_2 = temperature of sink

71. **(d)** Efficiency of engine

$$\eta_1 = 1 - \frac{T_2}{T_1} = \frac{1}{6}$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{5}{6} \qquad \text{....(i)}$$

When T_2 is lowered by 62K, then

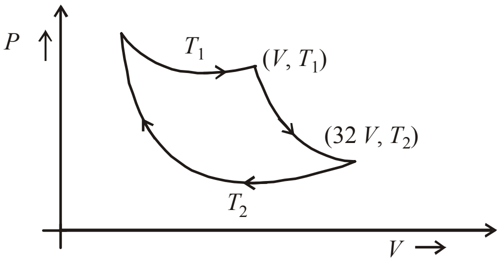
Again, $\eta_2 = 1 - \frac{T_2 - 62}{T_1}$

$$= 1 - \frac{T_2}{T_1} + \frac{62}{T_1} = \frac{1}{3} \qquad \text{....(ii)}$$

Solving (i) and (ii), we get,

$T_1 = 372$ K and $T_2 = \frac{5}{6} \times 372 = 310$ K

72. **(b)**



For adiabatic expansion $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

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

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

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

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

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

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

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

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

$$\beta = \frac{1-\eta}{\eta}$$

Also, $\beta = \frac{Q_2}{W}$

$$\therefore \beta = \frac{1-n}{n} = \frac{Q_2}{W}$$

$$\therefore \beta = \frac{1 - \frac{1}{10}}{\left(\frac{1}{10}\right)} = \frac{Q_2}{W}.$$

is independent of path taken by the process.

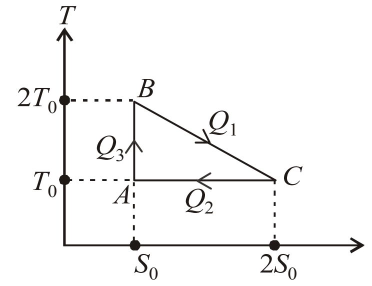
$$\Rightarrow 9 = \frac{Q_2}{10}$$

$$\Rightarrow Q_2 = 90 \text{ J.}$$

74. **(d)** Q_1 = area under BC $= T_0S_0 + \frac{1}{2}T_0S_0$

Q_2 = area under AC $= T_0(2S_0 - S_0) = T_0S_0$
and $Q_3 = 0$

Efficiency, $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$



$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_0 S_0}{\frac{3}{2} T_0 S_0} = \frac{1}{3}$$

75. **(b)** Internal energy and entropy are state function, they are independent of path taken.

76. **(a)** This is a consequence of second law of thermodynamics

77. **(b)** Here, $T_1 = 627 + 273 = 900$ K
$T_2 = 27 + 273 = 300$ K

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

$$= 1 - \frac{300}{900} = 1 - \frac{1}{3} = \frac{2}{3}$$

But $\eta = \frac{W}{Q}$

$$\therefore \frac{W}{Q} = \frac{2}{3} \Rightarrow W = \frac{2}{3} \times Q = \frac{2}{3} \times 3 \times 10^6$$

$= 2 \times 10^6$ cal

$= 2 \times 10^6 \times 4.2$ J $= 8.4 \times 10^6$ J

78. **(a)** All reversible engines have same efficiencies if they are working for the same temperature of source and sink. If the temperatures are different, the efficiency is different.

79. **(c)** In Carnot's cycle we assume frictionless piston, absolute insulation and ideal source and sink (reservoirs).

The efficiency of carnot's cycle $\eta = 1 - \frac{T_2}{T_1}$

The efficiency of carnot engine will be 100% when its sink (T_2) is at 0 K.

The temperature of 0 K (absolute zero) cannot be realised in practice so, efficiency is never 100%.