

Thermodynamics

Self-Assessment

Module 1 Scope of Thermodynamics

Q.12.1.1 Two small objects A and B (with A smaller of the two) are kept in contact, with a large object C such that they are not in direct contact with each other for a sufficient time. If A and B are now kept in contact with each other, there would be

- (A) a flow of heat from A to B,
- (B) a flow of heat from B to A.
- (C) no flow of heat between A and B as their total heat contents would have identical values.
- (D) no flow of heat between A and B as their temperatures would have identical values.

Q.12.1.2 The sequence of development of the three laws (zeroth, first and second law) is

- (A) first, second, zeroth
- (B) zeroth, first, second
- (C) second, first, zeroth
- (D) second, zeroth, first

Q.12.1.3 A thermodynamic variable is said to be a 'state variable' if its value depends only on the 'state of the system' and not on the way that 'state' has been arrived at.

Out of the following:

(Heat, work, internal energy)

the state variable/ variables, is/are

- (A) Heat and work
- (B) Work and internal energy
- (C) Internal energy
- (D) Heat

Q.12.1.4 The temperature of a system may be defined as a

(a) characteristic property of the system that determines whether or not this system would be in thermal equilibrium with another system.

(b) measure/an indicator of the kinetic energy of its molecules.

We refer to definitions (a) and (b),

(A) as, the kinetic theory based and the thermodynamic definitions of temperature, respectively.

(B) as the thermodynamic, and the kinetic theory based definitions of temperature, respectively.

(C) both as the kinetic theory-based definitions of temperature.

(D) both as the thermodynamic definitions of temperature.

Q.12.1.5 Two bodies A and B are in thermal equilibrium with each other. The volume of body A is four times that of body B. Assume that the heat contents of the two bodies are proportional to their respective volumes. The net amount of heat transferred, from A to B, when the two bodies are put in thermal contact with each other, would be

(A) $3/2$ times the heat content of B

(B) 3 times the heat content of B

(C) $3/8$ times the heat content of A

(D) Zero

Q.12.1.6 A person, of mass M kg, wants to lose m kg ($m \ll M$) by going up and down on stairs of height H .

Assume that he 'burns' twice as much fat while 'going up' than 'coming down' and 1 kg of fat gets 'burnt' on expending Q kilocalorie (1 calorie $\approx$ 4.2 joule). The number of cycles (of going 'up' and 'down') that he needs to undertake, to achieve his aim, would then equal:

(A) $\frac{2800mQ}{MgH}$

(B) $\frac{4200 \text{ mQ}}{MgH}$

(C) $\frac{667 \text{ mQ}}{MgH}$

(D) $\frac{1000 \text{ mQ}}{MgH}$

Q.12.1.7 The internal energy, of any general system,

- (A) can change only when the temperature of the system (ideal or practical) changes
- (B) can change only when the potential energy of the system (ideal/practical) changes
- (C) can change either when the temperature or the potential energy of the system (ideal/practical) changes
- (D) never changes irrespective of the changes it may undergo.

Q.12.1.8 The thermodynamic state of a system is described in terms of the values of its (usual), three state variables - the pressure (P), volume (V), and temperature (T).

If one of the thermodynamic states of a given system is written as (P_0, V_0, T_0) , the system would be said to be in a new thermodynamic state.

- (A) If, and only if, its state variables in this (new) state, have values nP_0, nV_0, nT_0 (n = an integer)
- (B) If and only if, all its three state variables in this (new) state, have values different from their initial values
- (C) If and only if, at least two of its state variables in this (new) state, have values different from their initial value.
- (D) If any one of its state variables, in this (new) state, has a value different from its initial value.

Q.12.1.9 System A is a hot light metal bar; system B is a large bucket of warm water and system C is the surrounding air. On putting them in mutual contact, heat would flow from system

- (A) B to system A
- (B) C to system B
- (C) C to system A
- (D) System A to system B, as well as from system A to system C

Q.12.1.10 Internal Energy of a system remains constant, when

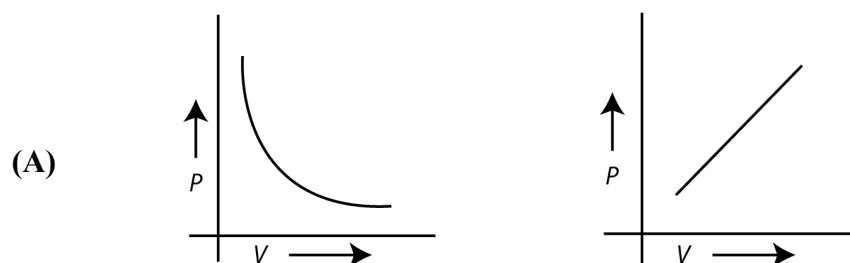
- (A) its pressure remains constant
- (B) its heat content remains constant
- (C) its volume remains constant
- (D) its temperature remains constant

Module 2 Thermodynamic Processes

Q.12.2.1 The pressure, volume and temperature of an ideal gas have values (P_0, V_0, T_0) in its initial state. It undergoes an expansion so that its volume becomes $V (V > V_0)$, in two different ways. The final pressure, volume and temperature values, in the two cases, are

- (i) (P, V, T_0)
- (ii) (P_0, V, T)

The $(P-V)$ diagrams, for the two cases (Fig.Q.12.2.1), then correspond, respectively, to



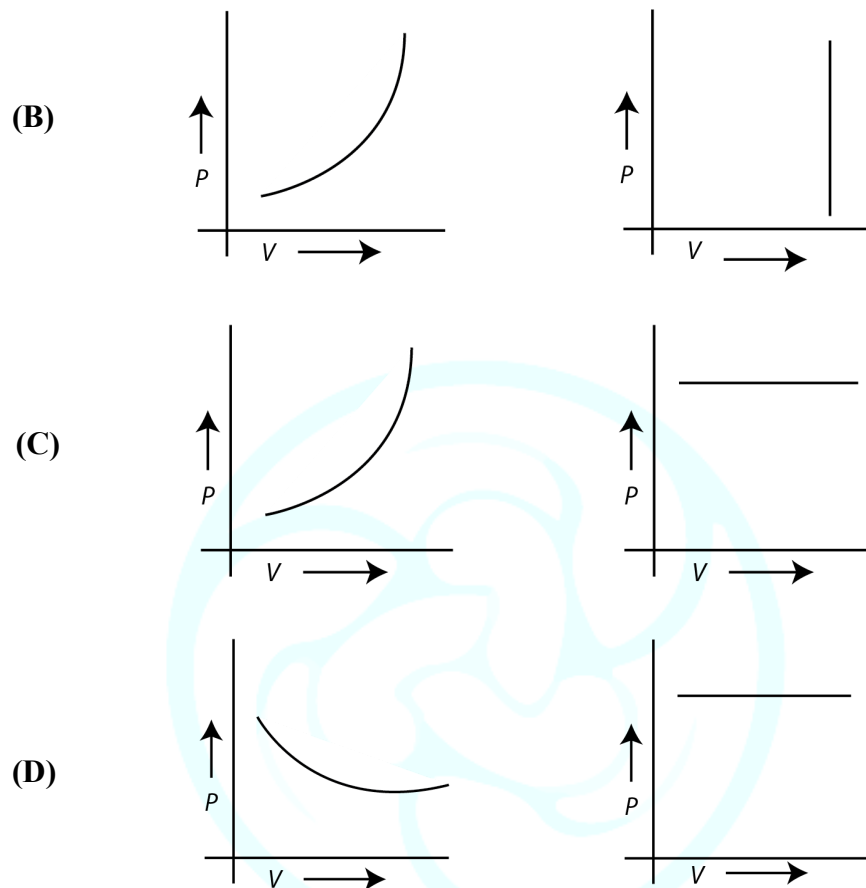


Fig.Q.12.2.1

Q.12.2.2 Heat is added to a system but its temperature does not change. This could be so because the system must have undergone an

- (A) isothermal change
- (B) isobaric change
- (C) isochoric change
- (D) adiabatic change

Q.12.2.3 Consider an ideal gas expanding through a process in which the pressure (P) and volume (V) are related as per the equation.

$$P = aV^3 + bV^2 + cV + d$$

The ratio of the slope of the $P - V$ graph for this process, to that for an adiabatic process, at some point (V_0, P_0) , would be

(A) $\frac{-1}{\gamma P_0} [3aV_0^2 + 2bV_0 + c]$

(B) $-\left[\frac{3aV_0^3 + 2bV_0^2 + cV_0}{\gamma P_0} \right]$

(C) $\gamma P_0 [3aV_0 + 2b + cV_0^{-1}]$

(D) $\gamma P_0 [3aV_0^2 + 2bV_0 + c]$

Q.12.2.4 The walls of a cylinder are made of a heat insulator and the movable piston, present in it, is insulated by keeping a light pile of sand on it.

The cylinder initially contains 3 moles of hydrogen at standard temperature and pressure. The piston is moved to compress the gas to half its original volume. The factor, by which the pressure of the gas would increase, is

(A) $2^{7/5}$

(B) $2^{5/3}$

(C) $2^{5/5}$

(D) $2^{7/3}$

Q.12.2.5 Two identical containers A and B each of volume V , contain, respectively,

(i) a monatomic (ii) a diatomic gas, at the same pressure and temperature.

The gas in container A is compressed to a volume ($V/4$) isothermally while that in container B is compressed to a volume $V/8$ adiabatically. The ratio of the final pressure in container B, to that in container A, would be

- (A) $(2^{11/5})$
- (B) 16
- (C) 8
- (D) $(2^{16/5})$

Q.12.2.6 The tube, in a cycle tyre of (fixed) volume V , is being filled with air from a pump. At each stroke of the pump, a (small) volume ΔV air is transferred to the tube adiabatically. Assuming air to be a diatomic gas, the work done, in increasing the air pressure in the tube from P_1 to P_2 , is (nearly)

- (A) $5/7 V (P_2 - P_1)$
- (B) $7/5 V (P_2 - P_1)$
- (C) $\frac{5}{3} V (P_2 - P_1)$
- (D) $\frac{3}{5} V (P_2 - P_1)$

Q.12.2.7 Imagine a heat engine following a cycle, represented by the P - V diagram shown in Fig.Q.12.2.2.

This cycle is made up of (i) an isothermal from state x to state y (ii) an adiabatic from state y to state z and (iii) an adiabatic from state z to state x .

Such a cycle is not permissible because

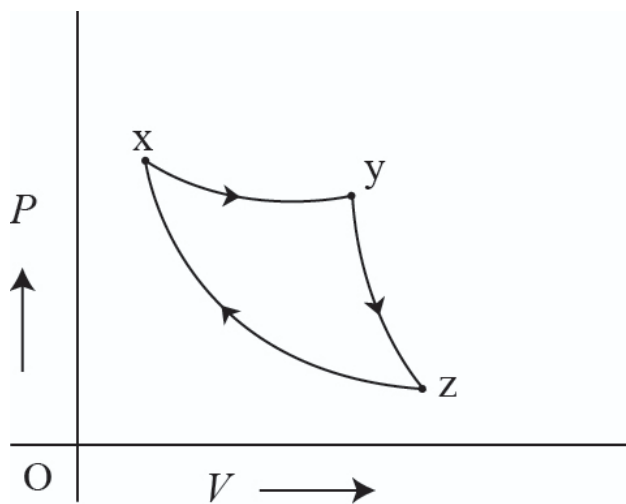


Fig.Q.12.2.2

- (A) It shows an isothermal (xy) intersecting with an adiabatic (yz).
- (B) It represents a cycle in which mechanical energy gets completely converted into heat which is not in accord with the second law of thermodynamics.
- (C) It represents a cycle in which heat gets completely converted into mechanical energy which is not in accord with the second law of thermodynamics.
- (D) It represents a cycle in which the internal energy (U) of the system in all the three states have different values, i.e., $U_x \neq U_y \neq U_z$.

Q.12.2.8 One mole of a perfect diatomic gas is taken adiabatically from an initial state (P, V, T) to a final state ($P, 32 V, T'$). The ratio $\left(\frac{T'}{T}\right)$ equals

(A) $2^{\frac{5}{3}}$

(B) $2^{\frac{25}{3}}$

(C) 2^{-2}

(D) 2^{-4}

Q 12.2.9 The PV diagram, of the cycle followed by a heat engine, having one mole of a perfect gas (in its cylinder - piston set up), is as shown in Fig. Q.12.2.3. The net work done by the engine, in one cycle is

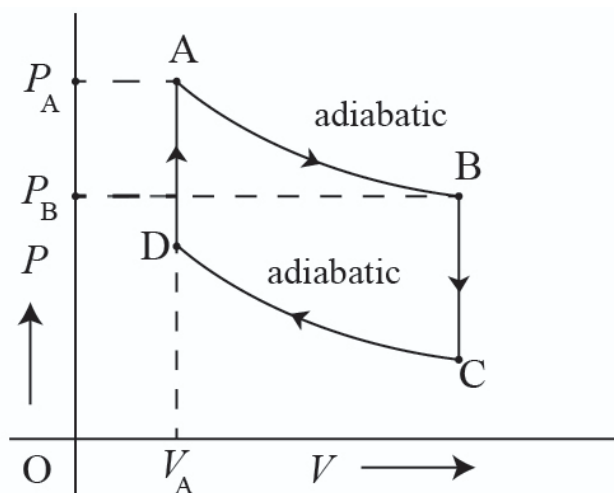


Fig.Q.12.2.3

(A) $\frac{1}{(1-\gamma)} [V_A(P_D - P_A) + V_B(P_B - P_C)]$

(B) $\frac{1}{(1-\gamma)} [V_A(P_B - P_A) + V_B(P_C - P_D)]$

(C) $\frac{1}{(1-\gamma)} [V_A(P_B + P_A) - V_B(P_C + P_D)]$

(D) $\frac{1}{(1-\gamma)} [V_A(P_D + P_A) - V_B(P_B + P_C)]$

Q.12.2.10 The P - V diagram, for a process of an ideal gas, has the form shown here (Fig.Q.12.2.4).

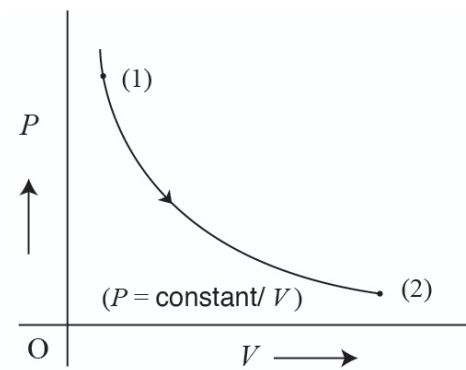
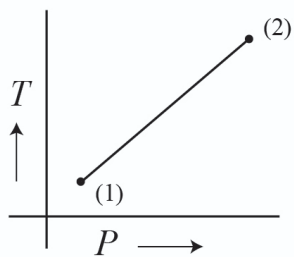


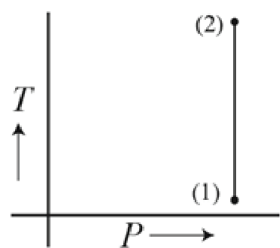
Fig.Q.12.2.4

The $(T-P)$ diagram for this gas would have the form

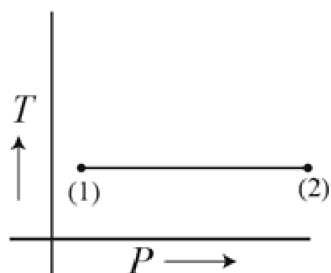
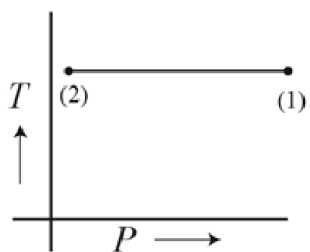
(A)



(B)



(C)



(D)

Q.12.2.11 The P - V diagram, for an ideal gas, has the form shown in Fig.Q.12.2.5.

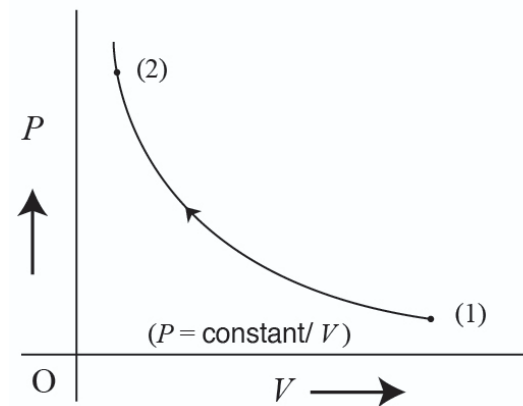
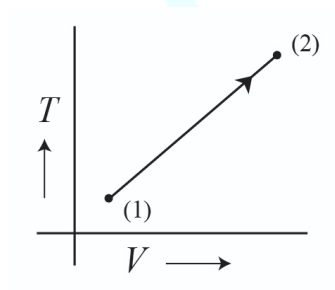


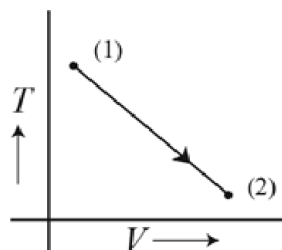
Fig.Q.12.2.5

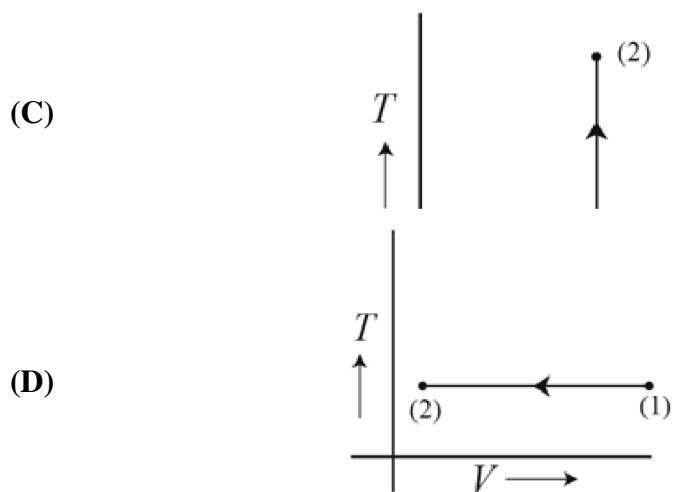
The $(T$ - V) diagram. For this gas, would have the form

(A)



(B)





Module 3 First Law of Thermodynamics

Q.12.3.1 A system goes from a state X to another state Y by two different ‘paths’, as shown in its $P-V$ diagram (Fig.Q.12.3.1). The heat given to the system, along path 1 is 1000 J while the work done by the system, along path 1, exceeds the work done by it along path 2, by 100 J. The heat given to the system, along path 2,

- (A) cannot be calculated from the given data
- (B) equals 1100 J
- (C) equals 900 J
- (D) would still be 1000 J as heat exchanged, between two given states, is a ‘path independent’ Variable.

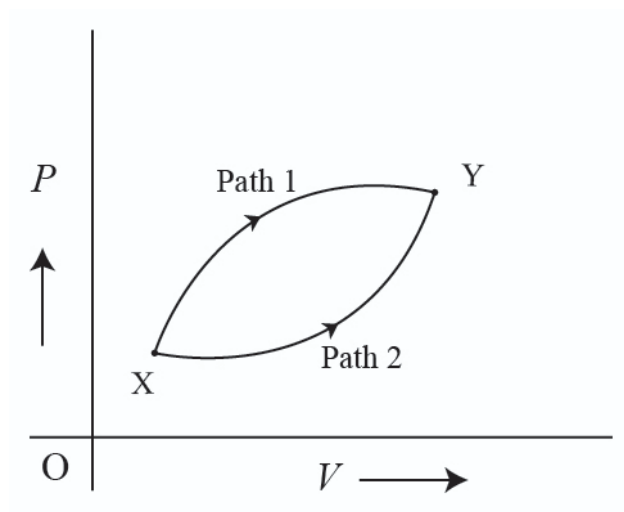


Fig.Q.12.3.1

Q.12.3.2 In the usual statement of the first law of thermodynamics, namely,

$$dQ = dU + dW$$

- (A) dU is (+ve) when the temperature of the system decreases and $dW = (-ve)$ when work is done by the system.
- (B) dU is (-ve) when the temperature of the system decreases and $dW = (-ve)$ when work is done by the system.
- (C) dU is (+ve) when the temperature of the system increases and $dW = (+ve)$ when work is done by the system.
- (D) dU is (-ve) when the temperature of the system increases and $dW = (-ve)$ when work is done by the system.

Q.12.3.3 An ideal gas undergoes an (i) isothermal change (ii) isochoric change, from some initial state (X) to a final state Y. We would then have

- (A) $dU = 0$ in case (i) and $dQ = 0$ in case (ii)
- (B) $dU = 0$ in case (i) and $dW = 0$ in case (ii)
- (C) $dW = 0$ in case (i) and $dU = 0$ in case (ii)

- (D) $dW = 0$ in case (i) and $dQ = 0$ in case (ii)

Q.12.3.4 An electric heater supplies heat to a system at a rate of 100 joule per second. If the system

- (i) does work at the rate of 75 joule per second
 - (ii) has work done on it at the rate of 75 joule per second,
the internal energy of the system
- (A) would increase at the rate of 25 joules per second in both the cases.
- (B) would increase at the rate of 25 joules per second in case (i) and at the rate of 175 joules per second in case (ii).
- (C) would increase at the rate of 175 joules per second in case (i) and at the rate of 25 joules per second in case (ii).
- (D) would decrease at the rate of 25 joules per second in case (i) and would increase at the rate of 25 joules per second in case (ii).

Q.12.3.5 A system goes from an equilibrium state A to another equilibrium state B via an adiabatic process.

During this process, work, equal to 22.3 J, is done on the system.

If this system were to be taken from the state A to state B, via another process in which the net heat absorbed by the system is 39.2 J, the net work done by the system would be

- (A) 16.9 J
- (B) 62.3 J
- (C) 22.3 J
- (D) 39.2 J

Q.12.3.6. The specific heat capacity of a given gas, at constant pressure, equals $(5/2) R$. η Moles of this gas are kept in a closed vessel of fixed volume V .

A possible name of this gas, and the rise in its temperature when an amount of heat Q is added to it, (at constant volume) are, respectively,

- (A) Hydrogen; $\left(\frac{2}{5} \frac{Q}{\eta R}\right)$
- (B) Oxygen; $\left(\frac{2}{7} \frac{Q}{\eta R}\right)$
- (C) Neon; $\left(\frac{2}{3} \frac{Q}{\eta R}\right)$
- (D) Helium; $\left(\frac{2}{7} \frac{Q}{\eta R}\right)$

Q.12.3.7. When an amount of heat ΔQ is given to a system, the system goes from an initial state A to a final state B. During this transition, the system does a work ΔW and its internal energy changes by an amount ΔU . This transition of the system can be brought about in a variety of ways. We can, however, say that in this transition.

- (A) ΔQ remains the same irrespective of the way the transition is brought about; ΔU and ΔW , however, depend on the path followed.
- (B) ΔW remains the same irrespective of the way the transition is brought about; ΔU and ΔQ , however, depend on the path followed.
- (C) ΔU remains the same irrespective of the way the transition is brought about; ΔQ and ΔW , however, depend on the path followed.
- (D) ΔQ , ΔW , ΔU all depend on the way the transition is brought about.

Q12.3.8. One mole of a monatomic (ideal) gas is taken from a point K to another point L, as shown on its P - V diagram (Fig.Q.12.3.2). The temperature of the gas, at point K, is T_0 . The change in the internal energy of the gas, during this transition, would equal

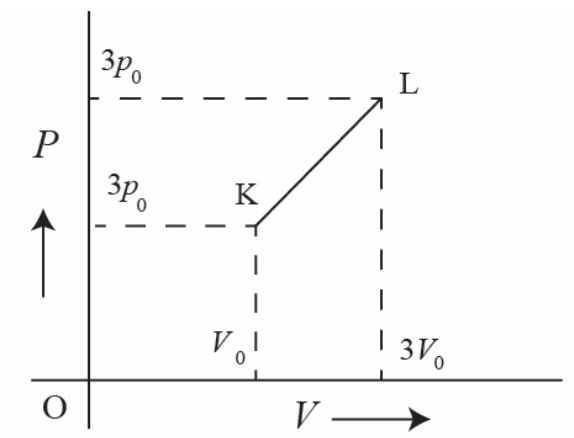


Fig.Q.12.3.2

- (A) $20 RT_o$
- (B) $16 RT_o$
- (C) $12 RT_o$
- (D) $8 RT_o$

Q.12.3.9 An ideal gas undergoes a change of state from a state A to another state B in four different ways - as per the P - V diagram shown here(Fig.Q.12.3.3). If the changes in the internal energy of the gas, in the four cases, are denoted by $\Delta U_1, \Delta U_2, \Delta U_3, \Delta U_4$, we would have

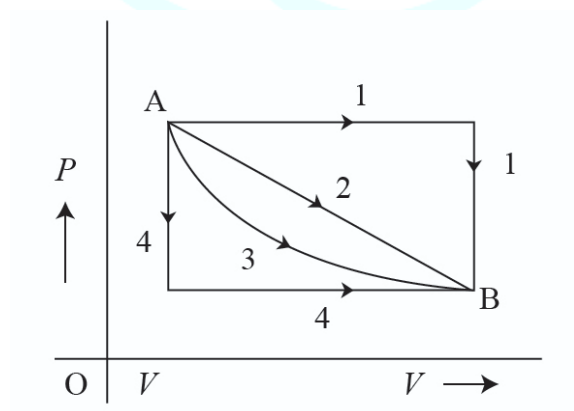


Fig.Q.12.3.3

(A) $\Delta U_1 > \Delta U_2 > \Delta U_3 > \Delta U_4$

(B) $\Delta U_1 > \Delta U_2 = \Delta U_3 > \Delta U_4$

(C) $\Delta U_1 < \Delta U_2 = \Delta U_3 < \Delta U_4$

(D) $\Delta U_1 = \Delta U_2 = \Delta U_3 = \Delta U_4$

Q.12.3.10 An ideal gas undergoes a change of state from a state A to another state B in three different ways (indicated by x, y, and z in Fig.Q.12.3.4 shown below). If the works done by the gas, in the three cases, are denoted by W_x , W_y and W_z we would have

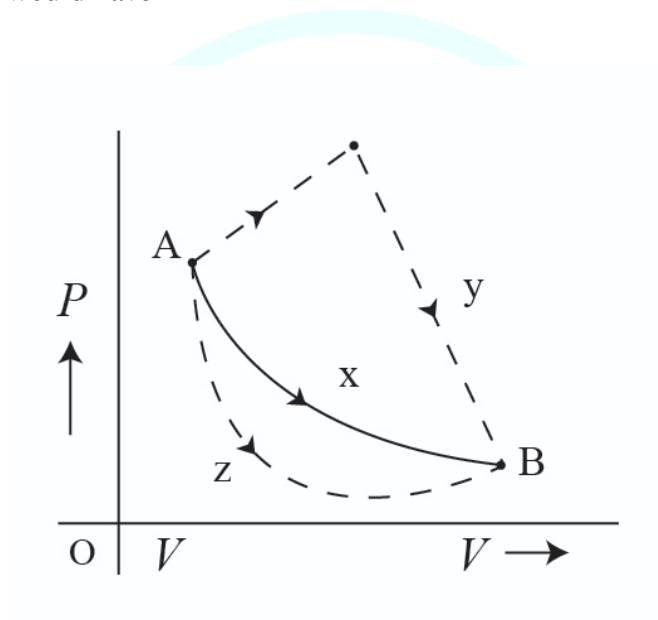


Fig.Q.12.3.4

(A) $W_x = W_y = W_z$

(B) $W_x > W_y > W_z$

(C) $W_y > W_x > W_z$

(D) $W_y > W_z > W_x$

Q 12.3.11 The temperature of the gas, present in a container, was increased without adding any heat to it. This change was brought about through an

- (A) isobaric expansion
- (B) isochoric compression
- (C) adiabatic compression
- (D) adiabatic expansion



Module 4 Second Law of Thermodynamics

Q.12.4.1 The coefficient of performance of a refrigerator is 9 and it is working in a room where the surrounding temperature is 27°C . The temperature, inside this refrigerator, is

- (A) 0°C
- (B) -1°C
- (C) -2°C
- (D) -3°C

Q.12.4.2 The coefficient of performance of a practical refrigerator, working between an inside temperature of -3°C and a surrounding temperature of 27°C , is 50% of that of an ideal refrigerator working between the same two temperatures. The electric motor, providing the needed mechanical work, has a power of 1 kW.

The heat, taken out of this refrigerator, per second, equals

- (A) 9.0 kJ
- (B) 4.5 kJ

- (C) 18 kJ
(D) 13.5 kJ

Q.12.4.3 The cycle followed by an engine (having one mole of a perfect gas in its cylinder-piston set up) is represented by the P - V diagram shown in Fig.Q.12.4.1. Given that $C_v = \frac{3}{2} R$, the heats exchanged by the engine with the surroundings, for each section of its cycle (in the order AB, BC, CD, DA) are equal, respectively, to

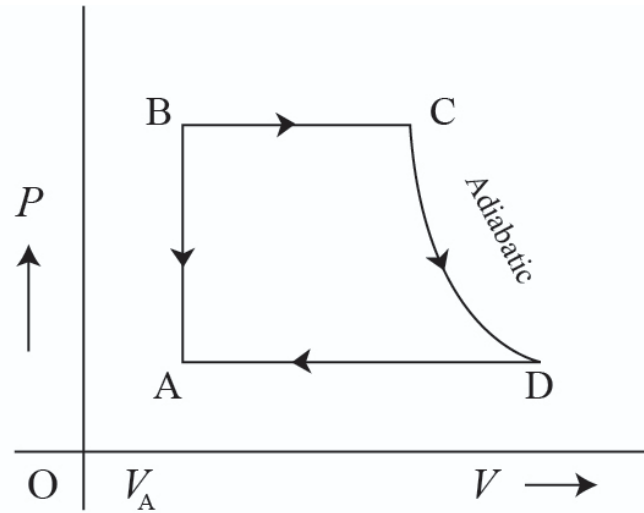


Fig.Q.12.4.1

- (A) $\left[\frac{3}{2} V_A (P_B - P_A) \right], \left[\frac{5}{2} P_B (V_C - V_B) \right], 0$ and $\frac{5}{2} [P_A (V_A - V_D)]$
 (B) $\left[\frac{5}{2} V_A (P_B - P_A) \right], \left[\frac{3}{2} P_B (V_C - V_B) \right], 0$ and $\left[\frac{5}{2} P_A (V_A - V_D) \right]$
 (C) $\left[\frac{3}{2} V_A (P_B - P_A) \right], \left[\frac{5}{2} P_B (V_C - V_D) \right], 0$ and $\frac{3}{2} [P_A (V_A - V_D)]$
 (D) $\left[\frac{3}{2} V_A (P_B - P_A) \right], \left[\frac{3}{2} P_B (V_C - V_D) \right], 0$ and $\left[\frac{3}{2} P_A (V_A - V_D) \right]$

Q.12.4.4. The surrounding temperature, for a refrigerator, equal 36°C . The temperature, is maintained at 9°C . The coefficient of performance is

- (A) 11.4
- (B) 10.4
- (C) 4.0
- (D) 1.9

Q.12.4.5. The coefficient of performance of a given refrigerator, operating in a room having a temperature of 27°C , equal 5. The temperature, inside the refrigerator, is

- (A) -33°C
- (B) -23°C
- (C) -13°C
- (D) -3°C

Q.12.4.6. A Carnot engine is working between a heat source of a temperature $T_1 = 500\text{ K}$ and a heat sink maintained at a temperature $T_2 = 300\text{ K}$. The mechanical work produced by the engine, per cycle, is 1 kJ . The heat, H_1 , taken in by the engine from the source and the heat, H_2 , given by the engine to the sink are then equal, respectively, to

- (A) 5.5 kJ and 4.0 kJ
- (B) 3.5 kJ and 2.5 kJ
- (C) 2.5 kJ and 1.5 kJ
- (D) 2.0 kJ and 1.0 kJ

Q.12.4.7. A heat engine, operating between a 'sink', at a temperature of 27°C , and a 'source' at a temperature of (327°C) , produces 1.4 kJ of mechanical work per cycle per calorie ($1\text{ calories} = 4.2\text{ J}$) of heat absorbed from the source. The ratio of the efficiency of this engine, to that of an ideal heat engine, operating between the same

'source' and 'sink' temperatures, is

- (A) $\frac{1}{3}$
- (B) $\frac{2}{3}$
- (C) $\frac{1}{2}$
- (D) $\frac{3}{4}$

Q.12.4.8. Consider a heat engine as shown in Fig.Q.12.4.2. Q_1 and Q_2 are heat is added to a heat bath at temperature T_1 and heat taken from another bath at temperature, T_2 during one cycle of an engine. W is the mechanical work done on the engine.

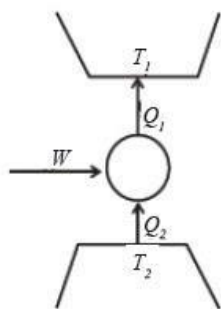


Fig.Q.12.4.2

If $W > 0$, the possibilities are:

- (A) $Q_1 > Q_2 > 0$
- (B) $Q_2 > Q_1 > 0$
- (C) $Q_2 = Q_1 < 0$
- (D) $Q_1 < 0, Q_2 > 0$

Q.12.4.9 The inside of an ideal refrigerator is at a temperature t_1 °C, its surroundings are at a temperature t_2 °C. the coefficient of performance of this refrigerator is (very nearly) equal one; if

- (A) $t_1 = 2t_2$
- (B) $t_1 = 2t_2 + 273$
- (C) $t_1 = t_2 + 273$
- (D) $t_1 = 2(t_2 + 273)$

Q.12.4.10 The heat source and the heat sink, being used with an ideal heat engine, are maintained at temperatures of t_1 °C and t_2 °C, respectively. The efficiency of this (ideal) heat engine would (very nearly) equal 25%, if

- (A) $t_1 = 4t_2$
- (B) $t_1 = \frac{4}{3}t_2 + 273$
- (C) $t_1 = \frac{4}{3}t_2 + 91$
- (D) $t_1 = \frac{4}{3}t_2 + 364$



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