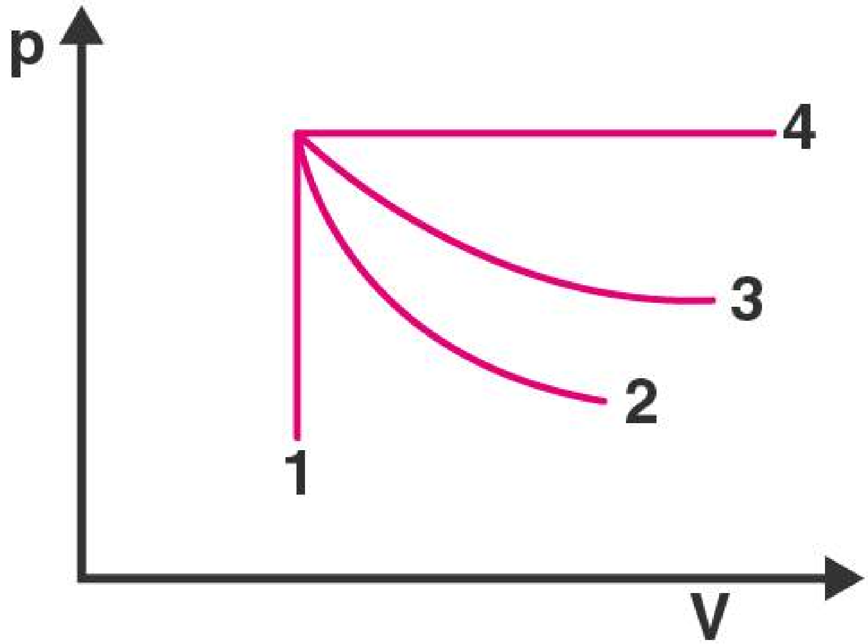
Multiple Choice Questions I

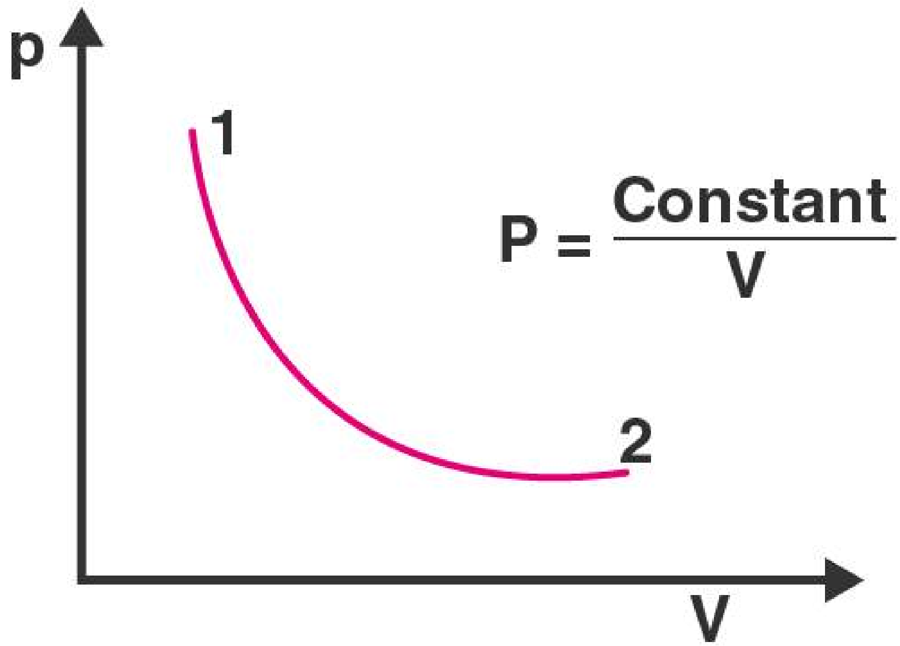
12.1. An ideal gas undergoes four different processes from the same initial state. Four processes are adiabatic, isothermal, isobaric, and isochoric. Out of 1, 2, 3, and 4 which one is adiabatic



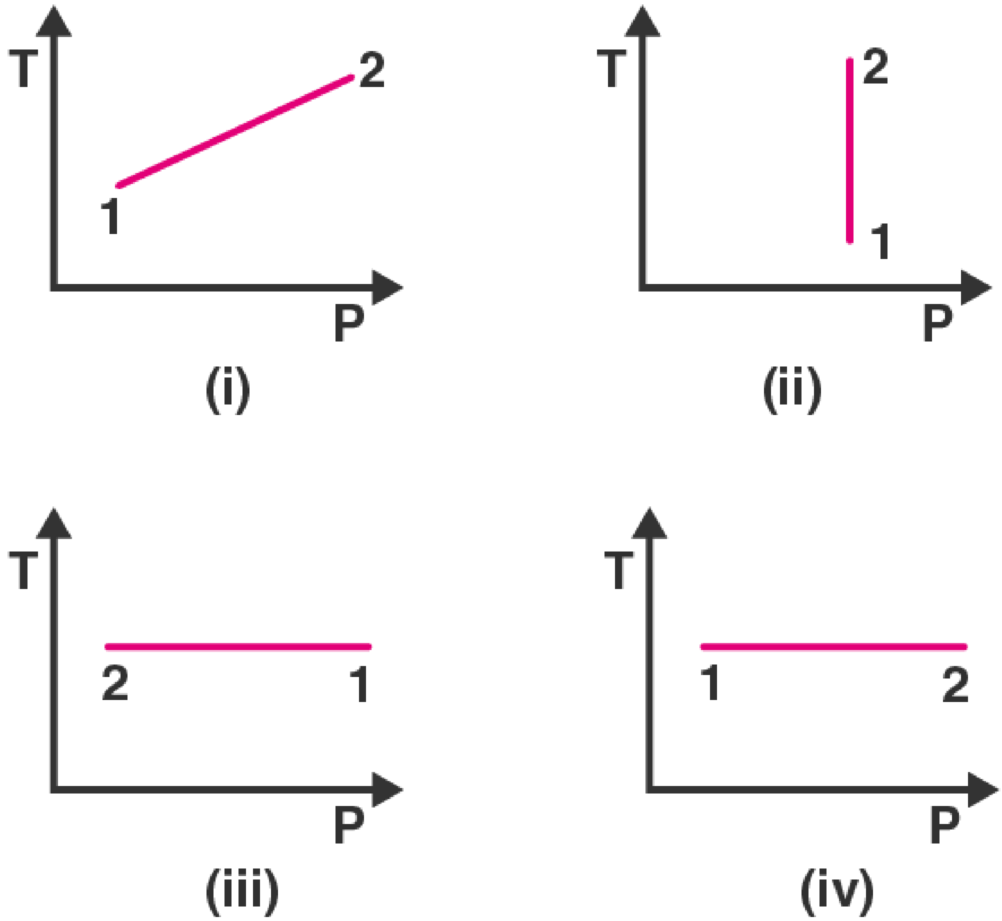
a) 4
b) 3
c) 2
d) 1
Answer:
The correct answer is c) 2

12.2. If an average person jogs, he produces 14.5×10^3 cal/min. This is removed by the evaporation of sweat. The amount of sweat evaporated per minute is assuming 1 kg requires 580×10^3 cal for evaporation
a) 0.25 kg
b) 2.25 kg
c) 0.05 kg
d) 0.20 kg
Answer:
The correct answer is a) 0.25 kg

12.3. Consider P-V diagram for an ideal gas shown in the figure.

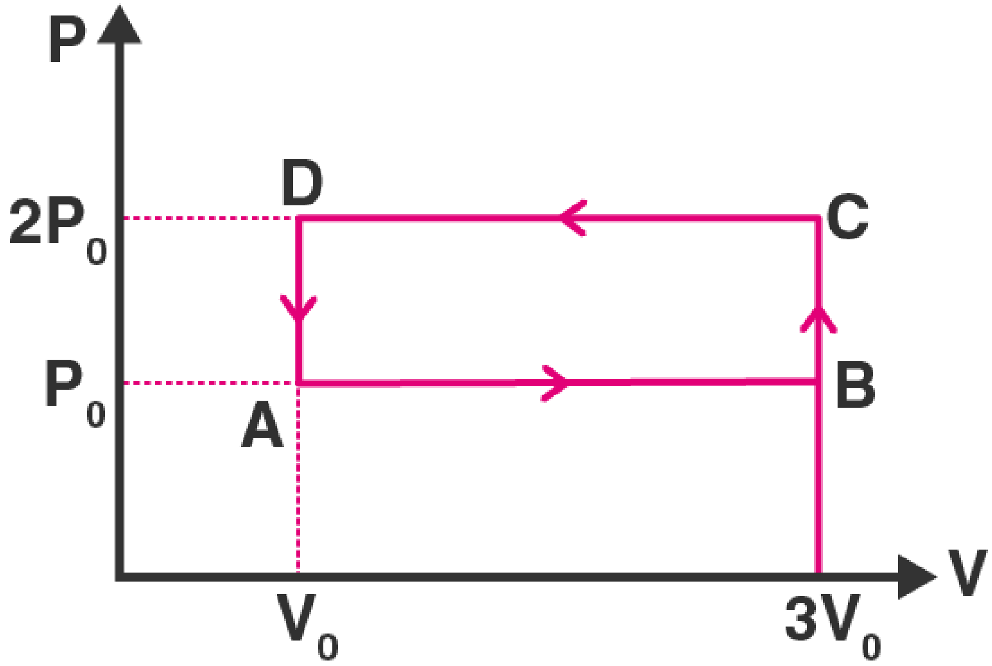


Out of the following diagrams, which represent the T-P diagram?



a) iv
b) ii
c) iii
d) i
Answer:
The correct answer is c) iii

12.4. An ideal gas undergoes cyclic process ABCDA as shown in the given P-V diagram. The amount of work done by the gas is



a) $6P_0V_0$
b) $-2P_0V_0$
c) $+2P_0V_0$
d) $+4P_0V_0$
Answer:
The correct answer is d) $+4P_0V_0$

12.5. Consider two containers A and B containing identical gases at the same pressure, volume, and temperature. The gas in container A is compressed to half of its volume isothermally while the gas in the container B is compressed to half of its original value adiabatically. The ratio of final pressure of gas in B to that of gas in A is

a)

$$2^{\gamma-1}$$

b)

$$(\frac{1}{2})^{\gamma-1}$$

c)

$$(\frac{1}{1-\gamma})^2$$

d)

$$\left(\frac{1}{\gamma-1}\right)^2$$

Answer:

The correct answer is a) $2^{\gamma-1}$

12.6. Three copper blocks of masses M_1, M_2, and M_3 kg respectively are brought into thermal contact till they reach equilibrium. Before contact, they were at T_1, T_2, T_3 ($T_1 > T_2 > T_3$). Assuming there is no heat loss to the surroundings, the equilibrium temperature T is

a)

$$T = \frac{T_1 + T_2 + T_3}{3}$$

b)

$$T = \frac{M_1T_1 + M_2T_2 + M_3T_3}{M_1 + M_2 + M_3}$$

c)

$$T = \frac{M_1T_1 + M_2T_2 + M_3T_3}{3(M_1 + M_2 + M_3)}$$

d)

$$T = \frac{M_1T_1s + M_2T_2s + M_3T_3s}{M_1 + M_2 + M_3}$$

Answer:

The correct answer is b) $$T = \frac{M_1T_1 + M_2T_2 + M_3T_3}{M_1 + M_2 + M_3}$$

Multiple Choice Questions II

12.7. Which of the process described below are irreversible?
a) the increase in temperature of an iron rod by hammering it
b) a gas in a small container at a temperature T_1 is brought in contact with a big reservoir at a higher temperature T_2 which increases the temperature of the gas
c) a quasi-static isothermal expansion of an ideal gas in cylinder fitted with a frictionless piston

d) an ideal gas is enclosed in a piston cylinder arrangement with adiabatic walls. A weight W is added to the piston resulting in compression of gas

Answer:

The correct answer is

a) the increase in temperature of an iron rod by hammering it

b) a gas in a small container at a temperature T_1 is brought in contact with a big reservoir at a higher temperature T_2 which increases the temperature of the gas

d) an ideal gas is enclosed in a piston cylinder arrangement with adiabatic walls. A weight W is added to the piston resulting in compression of gas

12.8. An ideal gas undergoes isothermal process from some initial state I to final state f. Choose the correct alternatives

a) dU = 0

b) dQ = 0

c) dQ = dU

d) dQ = dW

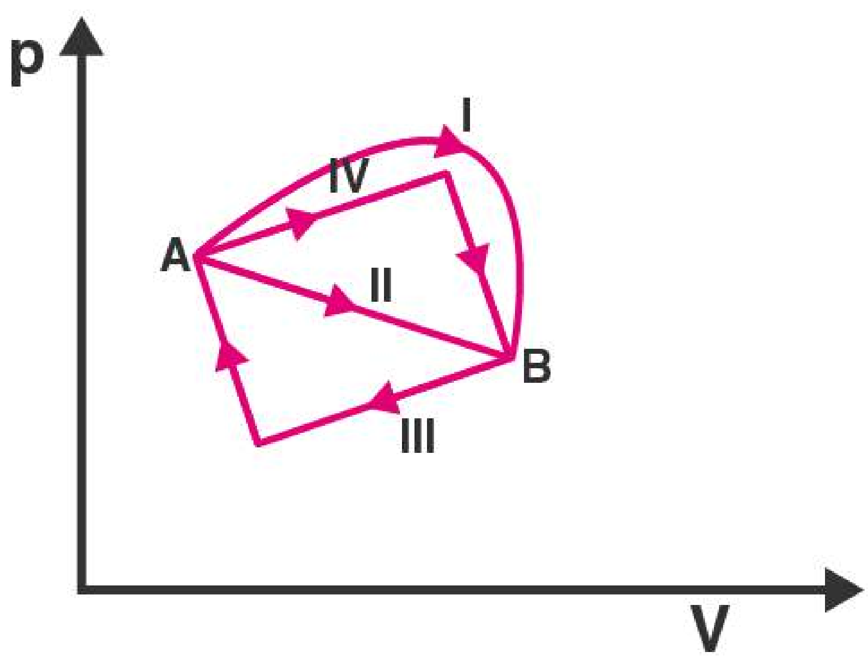
Answer:

The correct answer is

a) dU = 0

d) dQ = dW

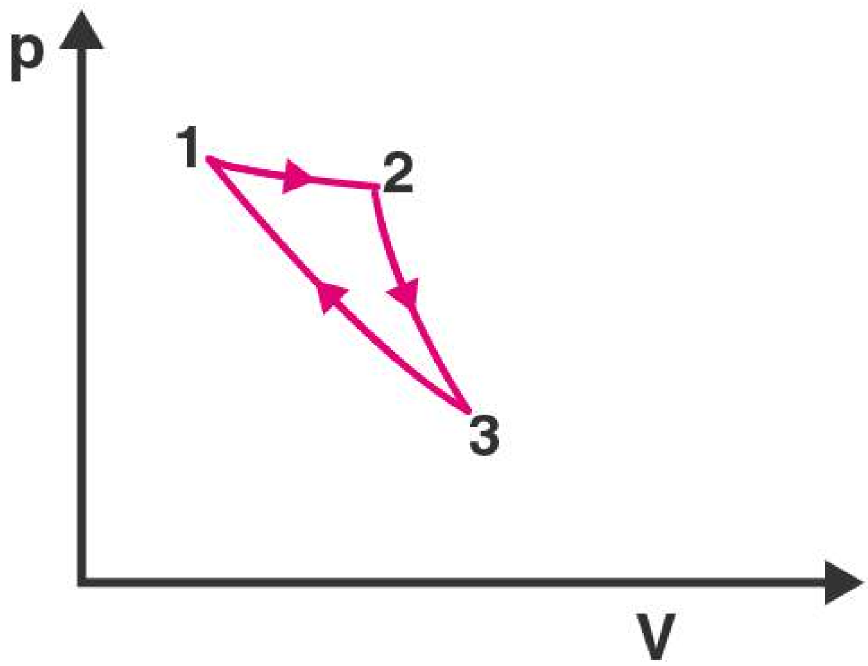
12.9 Figure shows the P-V diagram of an ideal gas undergoing a change of state from A to B. Four different parts I, II, III, and IV as shown in the figure may lead to the same changes of state.



a) change in internal energy is same in IV and III cases, but not in I and II

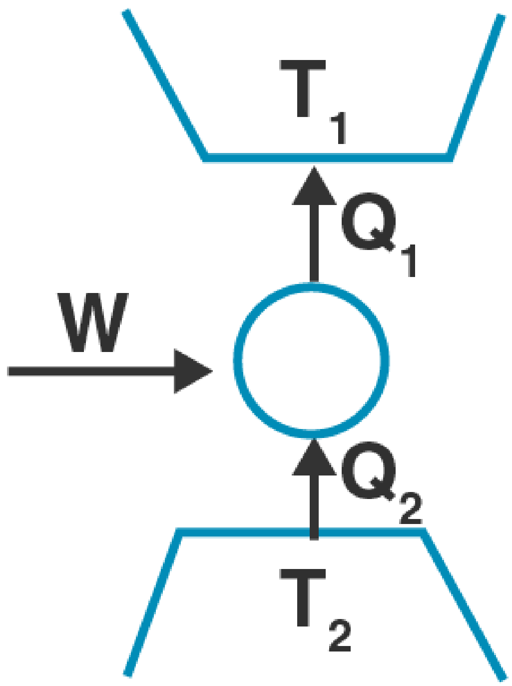
b) change in internal energy same in all the four cases
c) work done is maximum in case I
d) work done is minimum in case II
Answer:
The correct answer is
b) change in internal energy same in all the four cases
c) work done is maximum in case I

12.10. Consider a cycle followed by an engine



1 to 2 is isothermal
2 to 3 is adiabatic
3 to 1 is adiabatic
Such a process does not exist because
a) heat is completely converted to mechanical energy in such a process, which is not possible
b) mechanical energy is completely converted to heat in this process, which is not possible
c) curves representing two adiabatic processes don't intersect
d) curves representing an adiabatic process and an isothermal process don't intersect
Answer:
The correct answer is
a) heat is completely converted to mechanical energy in such a process, which is not possible
c) curves representing two adiabatic processes don't intersect

12.11. Consider a heat engine as shown on the figure. Q_1 and Q_2 are heat added to heat bath T_1 and heat taken from T_2 in one cycle of engine. W is the mechanical work done on the engine.



If W > 0, then possibilities are:
a) $Q_1 > Q_2 > 0$
b) $Q_2 > Q_1 > 0$
c) $Q_2 < Q_1 < 0$
d) $Q_1 < 0, Q_2 > 0$
Answer:
The correct answer is
a) $Q_1 > Q_2 > 0$
c) $Q_2 < Q_1 < 0$

Very Short Answers

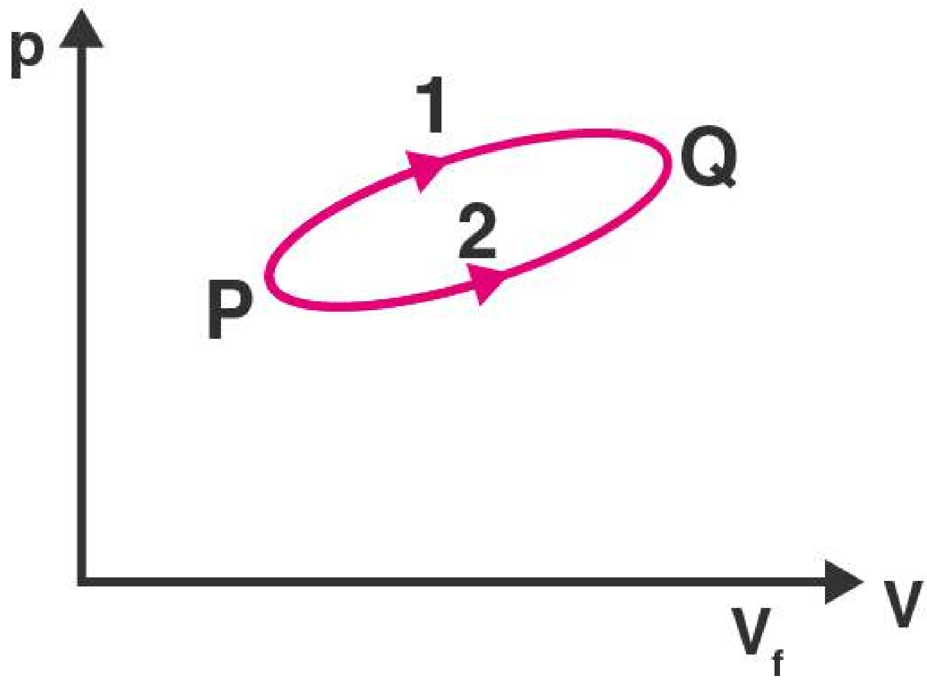
12.12. Can a system be heated and its temperature remains constant?
Answer:
For temperature to remain constant, the work done by the system against the surrounding should compensate with the heat that is supplied.
According to the given information,

$$\Delta T = 0 \Rightarrow \Delta U = 0$$

Therefore,

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

12.13. A system goes from P to Q by two different paths in the P-V diagram as shown in the figure. Heat given to the system in the path 1 is 1000 J. The work done by the system along path 1 is more than path 2 by 100 J. What is the heat exchanged by the system in path 2?



Answer:
From path 1, $Q_1 = +1000$ J
Work done = $W_1 - W_2 = 100$
Where,
W_1 is the work done through path 1
W_2 is the work done through path 2
Therefore, $W_2 = W_1 - 100$

$$\Delta U = Q_1 - W_1 = Q_2 - W_2$$

Substituting the values, we get $Q_2 = 900$ J

12.14. If a refrigerator's door is kept open, will the room becomes cool or hot? Explain.
Answer:
If a refrigerator's door is kept open, the room becomes hot because the amount of heat absorbed by the refrigerator and the work done by the refrigerator will be rejected to the room.

12.15. Is it possible to increase the temperature of a gas without adding heat to it? Explain.
Answer:
Yes, it is possible to increase the temperature of a gas without adding heat to it. This is possible during adiabatic compression.

12.16. Air pressure in a car tyre increases during driving. Explain.
Answer:
Air pressure in a car tyre increases during driving while the volume remains constant which is based on the Charle's law. Pressure is proportional to the temperature. Therefore, pressure of the gas increases.

Short Answers

12.17. Consider a Carnot's cycle operating between T_1 = 500K and T_2 = 300K producing 1 kJ of mechanical work per cycle. Find the heat transferred to the engine by the reservoirs.
Answer:
Given,
Temperature of the source, T1 = 500 K
Temperature of the sink, T2 = 300 K
Work done per cycle, W = 1 kJ = 1000 J
Heat transferred to the engine per cycle, Q1 = ?
Efficiency of a Carnot engine

$$\eta = 1 - \frac{T_2}{T_2} = 1 - \frac{300}{500} = \frac{2}{5}$$

$$\eta = \frac{W}{Q_1} \Rightarrow Q_1 = \frac{W}{\eta} = 2500J$$

$$Q_1 - Q_2 = W, Q_2 = Q_1 - W$$

= 2500 J – 1000 J = 1500 J

12.18. A person of mass 60 kg wants to lose 5 kg by going up and down a 10 m high stairs. Assume he burns twice as much fat while going up than coming down. If 1 kg of fat is burnt on expending 7000 kilo calories, how many times must he go up and down to reduce his weight by 5 kg?
Answer:
Given,
Height of the stairs, h = 10 m
Work done to burn 5 kg of fat = $(5)(7000 \times 10^3)(4.2) = 147 \times 10^6$ J
Work done towards burning of fat in one trip = mgh + 1/2 mgh = 3/2 mgh = $(3/2)(60)(10)(10) = 9 \times 10^3$ J
Therefore, no.of trips required = 16.3×10^3 times.

12.19. Consider a cycle tyre being filled with air by a pump. Let V be the volume of the tyre and at each stroke of the pump ΔV of air is transferred to the tube adiabatically. What is the work done when the pressure in the tube is increased from P_1 to P_2?
Answer:
Following is the equation before and after the stroke:

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$P(V+\Delta V)^{\gamma} = (P+\Delta P)V^{\gamma} \Rightarrow PV^{\gamma}(1+\frac{\Delta V}{V})^{\gamma} = P(1+\frac{\Delta P}{P})V^{\gamma}$$

$$PV^{\gamma}(1+\gamma\frac{\Delta V}{V}) \approx PV^{\gamma}(1+\frac{\Delta P}{P})$$

$$\gamma\frac{\Delta V}{V} = \frac{\Delta P}{P}$$

Therefore, work done is given as

$$W = \frac{(P_2 - P_1)V}{\gamma}$$

12.20. In a refrigerator one removes heat from a lower temperature and deposits to the surroundings at a higher temperature. In this process, mechanical work has to be done, which is provided by an electric motor. If the motor is of 1kW power, and heat is transferred from -3ºC to 27ºC, find the heat taken out of the refrigerator per second assuming its efficiency is 50% of a perfect engine.

Answer:

Efficiency of the Carnot engine is

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

Where

T_1 = 300 K

T_2 = 270 K

It is given that efficiency is 50% = 0.5

Efficiency of refrigerator = 0.05

We know that

$$\eta_{ref} = \frac{W}{Q_1} \Rightarrow Q_1 = \frac{W}{\eta_{ref}} = 20kJ$$

Therefore, efficiency of refrigerator is

$$Q_2 = Q_1 - \eta_{ref}Q_1 = Q_1(1-\eta_{ref}) = 19kJ$$

12.21. If the coefficient of performance of a refrigerator is 5 and operates at the room temperature, find the temperature inside the refrigerator.

Answer:

To find the temperature inside the refrigerator, we need to find the work done

W = 0

$Q_1 = Q_2$

$\beta = \infty$

Where β is the coefficient of performance

Given,

$T_1 = 27 + 273 = 300$ K

Coefficient of performance of refrigerator ω = 5

Coefficient of performance is given as

$$\beta = \frac{Q_2}{Q_1 - Q_2}$$

Using the above equation, temperature can be determined

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

$T_2 = -23^oC$.

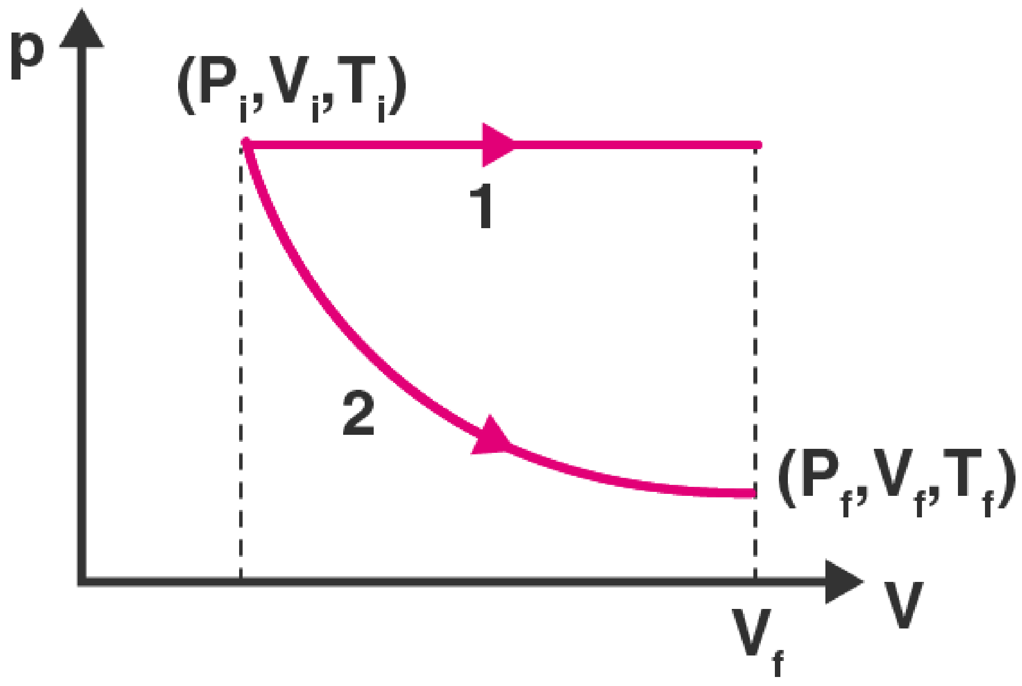
12.22. The initial state of a certain gas is P_i, V_i, T_i. It undergoes expansion till its volume becomes V_f. Consider the following two cases:

a) the expansion takes place at constant temperature

b) the expansion takes place at constant pressure

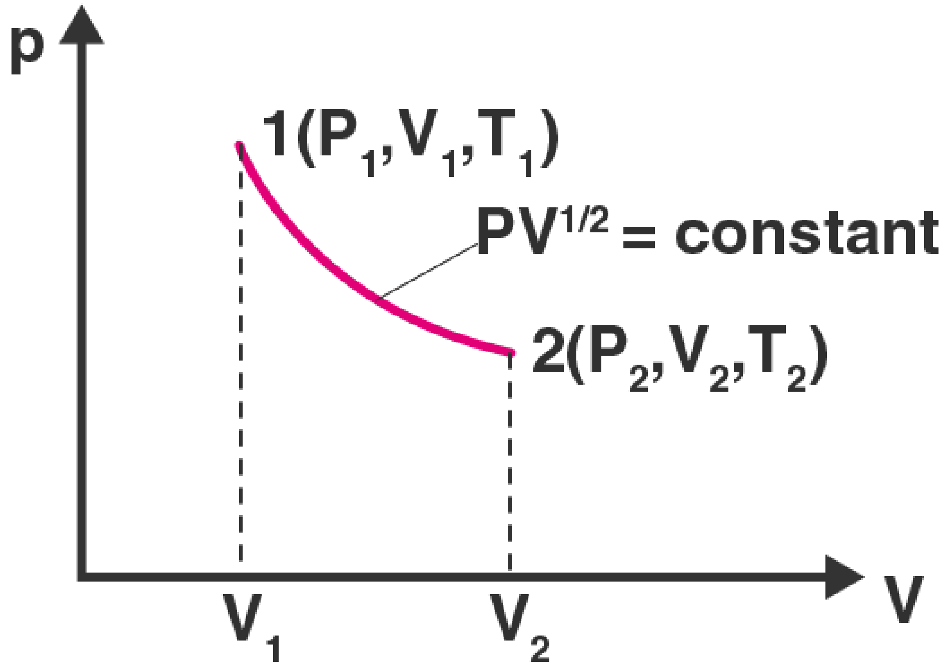
Plot the P-V diagram for each case. In which of the two cases, is the work done by the gas more?

Answer:



Long Answers

12.23. Consider a P-V diagram in which the path followed by one mole of perfect gas in a cylindrical container is shown in the figure.



a) find the work done when the gas is taken from state 1 to state 2
b) what is the ratio of temperature T_1/T_2 if $V_2 = 2V_1$
c) given the internal energy for one mole of gas at temperature T is (3/2)RT, find the heat supplied to the gas when it is taken from state 1 to 2 with $V_2 = 2V_1$.
Answer:
Given,
$PV^{1/2} = K$ = constant
a) Work done for the process 1 to 2

$$W_{1\to 2} = \int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} \frac{K}{\sqrt{V}} dV$$

Solving the above equation, we get

$$W_{1\to 2} = 2P_2V_2^{\frac{1}{2}}(\sqrt{V_2 - V_1})$$

b) Ideal gas equation is
PV = nRT
T = PV/nR

$$T = \frac{K\sqrt{V}}{nR}$$

$$T \propto \sqrt{V}$$

$$\frac{T_2}{T1} = \sqrt{\frac{V^2}{V_1}} = \sqrt{\frac{2V_1}{V_1}} = \sqrt{2}$$

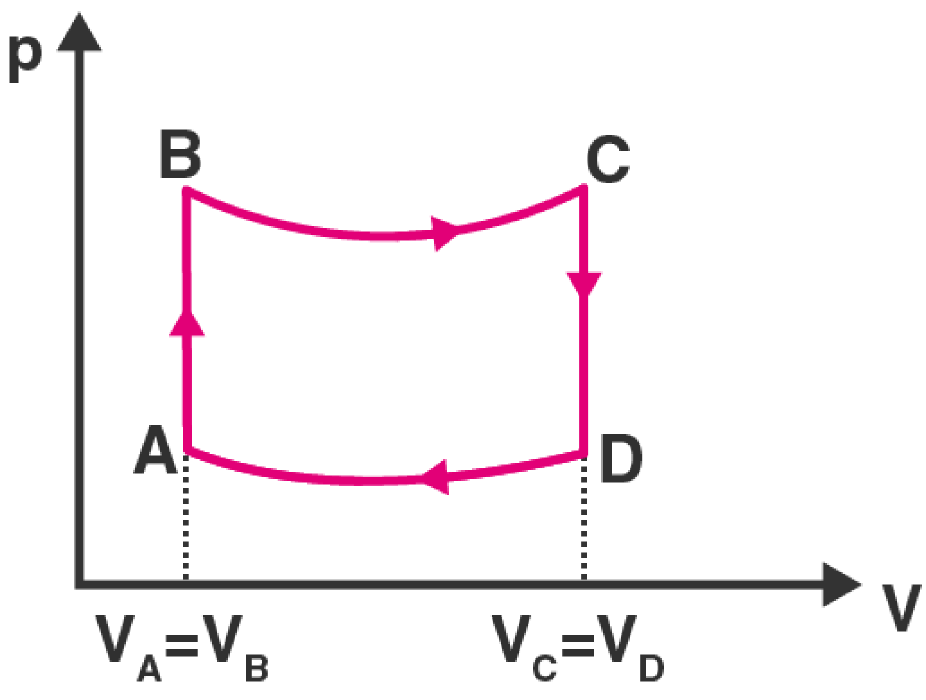
c) Internal energy, U = (3/2)RT

$$\Delta U = U_2 - U_1 = \frac{3}{2}R(T_2 - T_1) = \frac{3}{2}RT_1(\sqrt{2} - 1)$$

$$\Delta W = W_{1\to2} = 2P_1V_1^{\frac{1}{2}}(V_2^{\frac{1}{2}} - V_1^{\frac{1}{2}}) = 2RT_1(\sqrt{2} - 1)$$

$$\Delta Q = \Delta U + \Delta W = \frac{3}{2}RT_1(\sqrt{2} - 1) + 2RT_1(\sqrt{2} - 1) = \frac{7}{2}RT_1(\sqrt{2} - 1)$$

12.24. A cycle followed by an engine is shown in the figure.



A to B: volume constant
B to C: adiabatic
C to D: volume constant
D to A: adiabatic
$V_C = V_D = 2V_A = 2V_B$

a) in which part of the cycle heat is supplied to the engine from outside?
b) in which part of the cycle heat is being given to the surrounding by the engine?
c) what is the work done by the engine in one cycle in terms of P_A, P_B, V_A?
d) what is the efficiency of the engine?
Answer:
a) For process AB, the heat is supplied to the engine from outside.
dQ = dU + dW
dQ = dU = change in internal energy

b) For process CD, the volume remains constant and pressure decreases as the temperature for this process decreases.

c) Work done by the engine in one cycle in terms of P_A, P_B, V_A

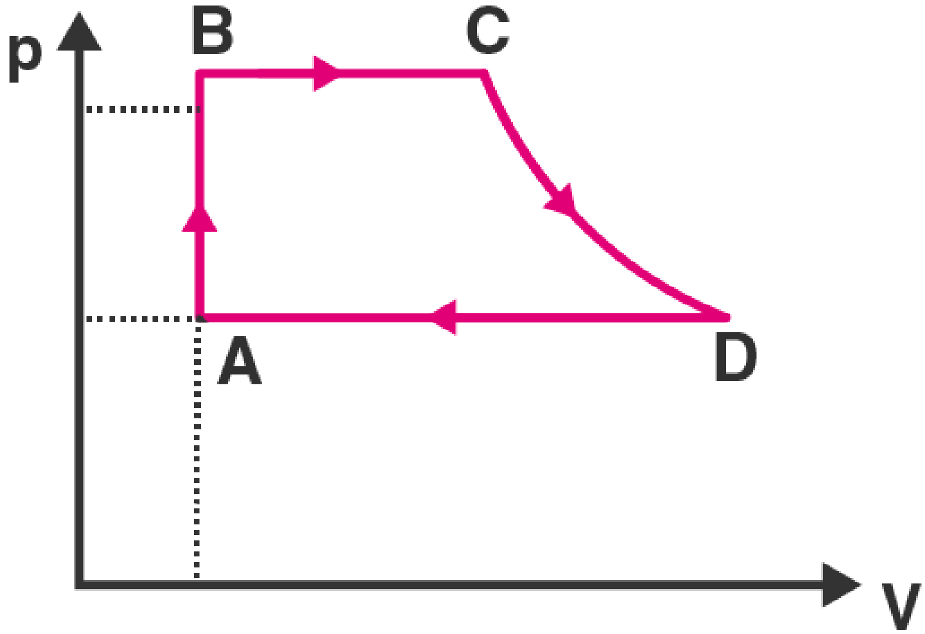
$$\int_A^B PdV + \int_B^C PdV + \int_C^D PdV + \int_D^A PdV$$

$$Work\ done = +\frac{3}{2}[1-(\frac{1}{2})^{\frac{2}{3}}][P_B - P_A]V_A$$

d) Efficiency is given as:

$$\eta = \frac{W}{Q} = [1-(\frac{1}{2})^{\frac{2}{3}}]$$

12.25. A cycle followed by an engine is shown in the figure. Find heat exchanged by the engine, with the surroundings for each section of the cycle considering C_v = (3/2)R.



AB: constant volume
BC: constant pressure
CD: adiabatic
DA: constant pressure
Answer:
a) AB: constant volume

$$\Delta Q = \Delta U + \Delta W = \Delta U + 0 = \Delta U$$

$$\Delta Q = \frac{3}{2}(P_B - P_A)V_A$$

b) BC: constant pressure

$$\Delta Q = \Delta U + \Delta W = \frac{5}{2}P_B(V_C - V_A)$$

c) CD: adiabatic QCD = 0

d) DA: constant pressure, there is compression of the gas from V_D to V_A at constant pressure P_A.

12.26. Consider that an ideal gas is expanding in a process given by P = f(V), which passes through a point (V_0, P_0). Show that the gas is absorbing heat at (P_0, V_0) if the slope of the curve P = f(V) is larger than the slope of the adiabat passing through (P_0, V_0).
Answer:
Slope of graph,

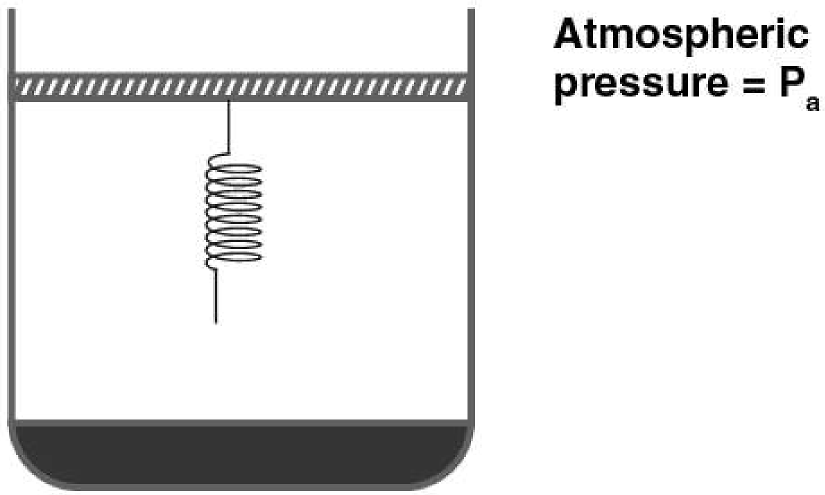
$$(V_0, P_0) = (\frac{dP}{dV})_{V_0,P_0}$$

Using the above relation, we can find that

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

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

12.27. Consider one mole of perfect gas in a cylinder of unit cross section with a piston attached. A spring is attached to the piston and to the bottom of the cylinder. Initially the spring is unstretched and the gas is in equilibrium. A certain amount of heat Q is supplied to the gas causing an increase of volume from V_0 to V_1.



a) what is the initial pressure of the system?
b) what is the final pressure of the system?
c) using the first law of thermodynamics, write down the relation between Q, P_a, V, V_0, and k.
Answer:
a) The initial pressure of the system inside the cylinder is = P_a

b) The final pressure of the system is = P_f
$P_f = P_a + K (V_1 – V_0)$
Where $V_1 – V_0$ is the increase in volume

c) The relation between Q, P_a, V, V_0, and k is:
$dQ = dU + dW$
$dU = C_v (T – T_0)$

Where,
T is the final temperature of gas
T_0 is the initial temperature of gas
n = 1

$$T_y = T = \frac{P_f V_f}{R} = \frac{P_a + K(V_1 - V_0)V_1}{R}$$

Work done by the gas is given as:

$$dW = P_a(V_1 - V_0) + \frac{1}{2}kx^2$$

dQ = dU + dW

Using these equation, we get the following required relation:

$$dQ = C_v(T - T_0) + P_a(V_1 - V_0) + \frac{1}{2}k(V_1 - V_0)^2$$