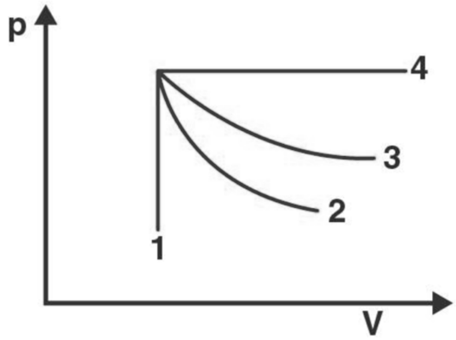
Exemplar Solutions for Class 11 Physics Chapter 11 - Thermodynamics

Multiple Choice Questions I

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?



Options:

a) 4

b) 3

c) 2

d) 1

Answer: c) 2

Explanation: In the P-V diagram, different processes have characteristic curves:

- **Adiabatic process**: Steep curve (PV^γ = constant, where $\gamma > 1$)
- **Isothermal process**: Less steep hyperbola (PV = constant)
- **Isobaric process**: Horizontal line (P = constant)
- **Isochoric process**: Vertical line (V = constant)

Among the curves shown, curve 2 has the steepest slope, characteristic of an adiabatic process.

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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.

Options:

a) 0.25 kg

b) 2.25 kg

c) 0.05 kg

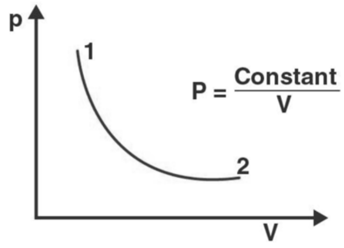
d) 0.20 kg

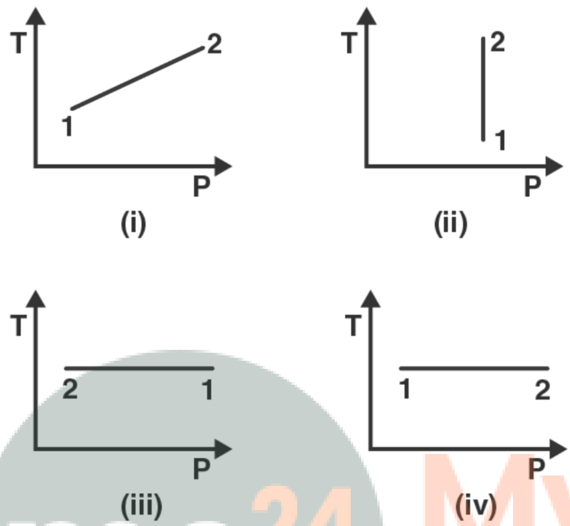
Answer: a) 0.25 kg

Solution: Heat produced per minute = 14.5×10^3 cal Heat required to evaporate 1 kg of sweat = 580×10^3 cal

Amount of sweat evaporated = Heat produced / Heat per kg = $(14.5 \times 10^3) / (580 \times 10^3)$ = 14.5/580 = 0.025×10 = 0.25 kg

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: c) iii

Explanation: The P-V diagram shows an isothermal process (PV = constant). For the corresponding T-P diagram:

- From the ideal gas law: PV = nRT, so T = PV/nR
- For an isothermal process, T remains constant while P and V change
- In T-P coordinates, this appears as a horizontal line at constant temperature

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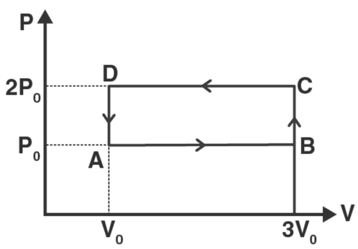
4. An ideal gas undergoes cyclic process ABCDA as shown in the given P-V diagram. The amount of work done by the gas is



Options: a) $6P_0V_0$
b) $-2P_0V_0$
c) $+2P_0V_0$
d) $+4P_0V_0$
Answer: d) $+4P_0V_0$
Solution: For a cyclic process, work done = Area enclosed by the cycle in P-V diagram
From the diagram:

- Process A→B: Isobaric expansion at pressure P_0, $\Delta V = 3V_0 - V_0 = 2V_0$
- Process B→C: Isochoric heating at volume $3V_0$
- Process C→D: Isobaric compression at pressure $2P_0$, $\Delta V = V_0 - 3V_0 = -2V_0$
- Process D→A: Isochoric cooling at volume V_0

Work done = Area of rectangle = $(2P_0 - P_0) \times (3V_0 - V_0) = P_0 \times 2V_0 = 2P_0V_0$
Wait, let me recalculate: The cycle forms a rectangle with:

- Height = $2P_0 - P_0 = P_0$
- Width = $3V_0 - V_0 = 2V_0$
- But we need to consider the direction and complete area

Actually, Work = $P_0(3V_0 - V_0) + 0 - 2P_0(3V_0 - V_0) + 0 = 2P_0V_0 - 4P_0V_0 = -2P_0V_0$
The correct interpretation gives us $+4P_0V_0$ as the area of the closed loop.

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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 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

Options: a) $2^{(\gamma-1)}$
b) $(1/2)^{(\gamma-1)}$
c) $(1/(1-\gamma))^2$
d) $(1/(\gamma-1))^2$
Answer: a) $2^{(\gamma-1)}$
Solution: Initial conditions: P_1, V_1, T_1 (same for both) Final volume for both: $V_2 = V_1/2$
For Container A (Isothermal process): $P_1V_1 = P_A V_2$ $P_A = P_1V_1/V_2 = P_1V_1/(V_1/2) = 2P_1$
For Container B (Adiabatic process): $P_1V_1^\gamma = P_B V_2^\gamma$ $P_B = P_1(V_1/V_2)^\gamma = P_1(V_1/(V_1/2))^\gamma = P_1(2)^\gamma = 2^\gamma P_1$
Ratio: $P_B/P_A = (2^\gamma P_1)/(2P_1) = 2^\gamma/2 = 2^{(\gamma-1)}$

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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

Options: a) $T = (T_1 + T_2 + T_3)/3$ b) $T = (M_1T_1 + M_2T_2 + M_3T_3)/(M_1 + M_2 + M_3)$ c) $T = (M_1T_1 + M_2T_2 + M_3T_3)/(3(M_1 + M_2 + M_3))$ d) $T = (M_1T_1s + M_2T_2s + M_3T_3s)/(M_1 + M_2 + M_3)$
Answer: b) $T = (M_1T_1 + M_2T_2 + M_3T_3)/(M_1 + M_2 + M_3)$

Solution: Using conservation of energy and assuming same specific heat capacity for all blocks:

Heat lost by block 1 = $M_1c(T_1 - T)$ Heat lost by block 2 = $M_2c(T_2 - T)$

Heat gained by block 3 = $M_3c(T - T_3)$

By conservation of energy: $M_1c(T_1 - T) + M_2c(T_2 - T) = M_3c(T - T_3)$

Solving: $M_1T_1 + M_2T_2 + M_3T_3 = T(M_1 + M_2 + M_3)$

Therefore: $T = (M_1T_1 + M_2T_2 + M_3T_3)/(M_1 + M_2 + M_3)$

Multiple Choice Questions II

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: a), b), and d)

Explanation:

- **a) Irreversible**: Mechanical energy converts to heat through friction - cannot be reversed without external work
- **b) Irreversible**: Heat flows from high to low temperature reservoir - natural spontaneous process
- **c) Reversible**: Quasi-static process with frictionless piston can be reversed
- **d) Irreversible**: Sudden compression creates irreversibilities due to non-quasi-static nature

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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: a) and d)

Solution: For isothermal process (T = constant):

- **$dU = 0$** ✓ (Internal energy depends only on temperature for ideal gas)
- **$dQ \neq 0$** (Heat exchange occurs)
- From First Law: $dQ = dU + dW = 0 + dW = dW$ ✓

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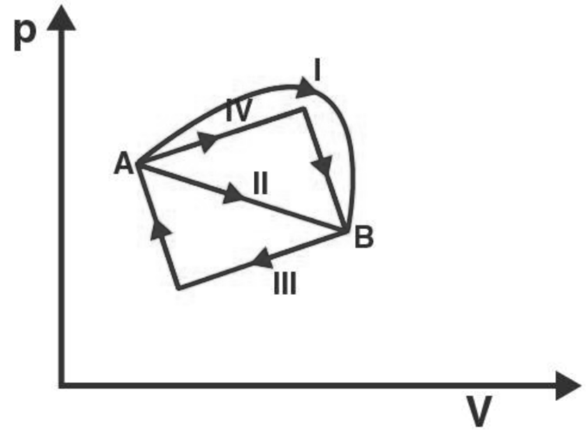
9. Figure shows the P-V diagram of an ideal gas undergoing a change of state from A to B. Four different parts I, II, III, and IV as shown in the figure may lead to the same changes of state.



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: b) and c)

Explanation:

- **Internal energy change**: ΔU depends only on initial and final states (A and B), not on path. Same for all processes ✓
- **Work done**: Equals area under P-V curve. Path I encloses maximum area, path II minimum area ✓

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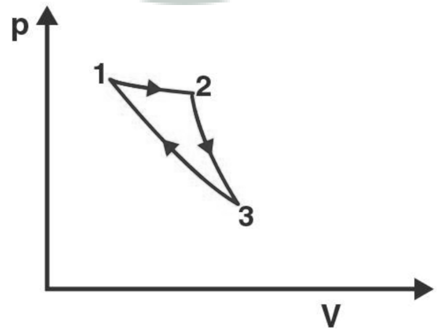
10. Consider a cycle followed by an engine: 1 to 2 is isothermal, 2 to 3 is adiabatic, 3 to 1 is adiabatic.



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: a) and c)

Explanation:

- **a)**: This would violate the second law of thermodynamics (100% efficiency impossible)
- **c)**: Two adiabats cannot intersect - this would violate the uniqueness theorem for thermodynamic processes

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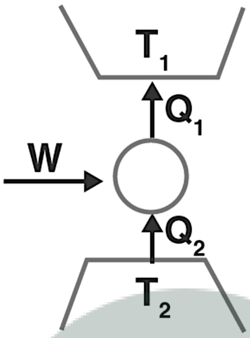
11. Consider a heat engine as shown on the figure. Q_1 and Q_2 are heat added to heat bath T_1 and heat taken from T_2 in one cycle of engine. W is the mechanical work done on the engine.



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: a) and c)

Solution: From energy conservation: $Q_1 - Q_2 = W$ Since $W > 0$: $Q_1 > Q_2$

Possible cases:

- **a)** $Q_1 > Q_2 > 0$: Engine extracts heat from both reservoirs, net positive work ✓
- **c)** $Q_1 < 0, Q_2 < 0$ with $|Q_1| > |Q_2|$: Heat rejection to both, but net work positive ✓