



Attempt questions first; check the separate key afterward. Use $\Delta U = Q - W$, where W is work done by the gas. Treat gases as ideal unless stated.

A. Very short answers - 1 mark each

1. What is a thermodynamic state variable? Give two examples.
2. State the zeroth law of thermodynamics.
3. Distinguish a system from its surroundings.
4. Can a gas receive heat without its temperature increasing? Give an example.
5. What is a cyclic process?
6. Why are heat and work path-dependent quantities?

B. Short answers / practice - 2 marks each

7. State the first law using work done by the gas as positive.
8. A gas receives 500 J heat and does 180 J work. Find the change in internal energy.
9. A gas is compressed with 200 J work done on it while losing 80 J heat. Find its internal-energy change.
10. Distinguish isothermal and adiabatic processes.
11. Why is work zero in an isochoric process?
12. What does the area enclosed by a clockwise loop on a P-V graph represent?
13. Explain why rapid compression heats air in a bicycle pump.
14. Is internal energy a state function?
15. Find work at constant pressure 10^5 Pa for expansion by 0.002 m^3 .
16. Does an ideal gas change internal energy in an isothermal process?
17. A cycle has net heat 120 J. Find net work done by the gas.
18. Compare heat and work as modes of energy transfer.

C. Application / reasoning - 3 marks each

19. An ideal gas expands at 2×10^5 Pa from 2 L to 5 L and receives 900 J heat. Find work and internal-energy change.
20. A gas completes a cycle absorbing 800 J heat and rejecting 500 J. Find net work and internal-energy change.

21. Explain reversible and irreversible processes. Give two causes of irreversibility.

22. Sketch isothermal and adiabatic expansions from the same state. Explain why the adiabatic curve is steeper.

23. A gas goes from A to B with $\Delta U = 120 \text{ J}$. In one path it does 80 J work; in another it receives 150 J heat. Find the heat in the first path and work in the second.

24. An ideal gas in one half of an insulated rigid vessel expands freely into the evacuated half. Find work, heat and temperature change; explain whether the process is reversible.

25. One mole of a monatomic ideal gas is heated at constant volume through 20 K. Find heat and internal-energy change using $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.

26. State the Kelvin-Planck and Clausius forms of the second law. Explain what each rules out.

D. Extended practice - 5 marks each

27. Derive work done in a reversible isothermal expansion of an ideal gas. One mole at 300 K doubles its volume; find work and heat using $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.

28. Using the first law and ideal-gas equation, derive $C_p - C_v = R$ for one mole. Explain physically why C_p exceeds C_v .

29. Using $PV^\gamma = \text{constant}$, derive work done in a reversible adiabatic expansion. Relate it to temperature change and internal-energy change.

30. A rectangular clockwise P-V cycle has corners (1 L, 1×10^5 Pa), (1 L, 3×10^5 Pa), (3 L, 3×10^5 Pa) and (3 L, 1×10^5 Pa). Draw the cycle; find work on each leg, net work and net heat.

ANSWER KEY - Numerical / closed questions

4) Yes; during isothermal ideal-gas expansion, heat becomes work. 8) 320 J. 9) 120 J. 14) Yes. 15) 200 J. 16) No. 17) 120 J. 19) 600 J; $\Delta U = 300 \text{ J}$. 20) 300 J; $\Delta U = 0$. 23) $Q_1 = 200 \text{ J}$; $W_2 = 30 \text{ J}$. 24) $W = Q = 0$; $\Delta T = 0$; irreversible. 25) $Q = \Delta U = 249.3 \text{ J}$. 27) $W = Q \approx 1728 \text{ J}$. 30) Leg work 0, +600, 0, -200 J; net work = net heat = 400 J.