

Heat, work and engines on PV diagrams

AP Physics 2 (algebra-based) · Test answers (mark scheme)

The model answers show the expected steps. Award marks for the correct sign convention and for reasoning in terms of energy, not only for numerical answers. Apply follow-through marking when a later part reuses an earlier wrong value correctly.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 9

Question 1 First law with numbers (3 marks)

- a. $Q = +500 \text{ J}$ and $W = -200 \text{ J}$.
- b. $\Delta U = 500 - 200 = \mathbf{+300 \text{ J}}$.
- c. $\Delta T = 300 / (1.5 \times 0.10 \times 8.31) = \mathbf{241 \text{ K}}$.

Marking: 1 mark per part; sign of W needed in part a.

Question 2 A two-step path (3 marks)

- a. $p\Delta V = 1.5 \times 10^5 \times 2.0 \times 10^{-3} = \mathbf{300 \text{ J}}$.
- b. $p_A V_A = 1.5 \times 10^5 \times 1.0 \times 10^{-3} = 150 \text{ J}$ and $p_C V_C = 0.5 \times 10^5 \times 3.0 \times 10^{-3} = 150 \text{ J}$. Equal pV means equal T .
- c. $\Delta U = 0$, and B to C does no work, so $Q = -W = \mathbf{+300 \text{ J}}$.

Marking: 1 mark per part.

Question 3 Process types (2 marks)

- a. $W = 0$, so $\mathbf{Q = \Delta U}$.
- b. $\Delta U = 0$ because T is constant, so the energy comes from heat flowing in from the surroundings ($Q = -W$).

Marking: 1 mark each part.

Question 4 An engine claim (3 marks)

- a. $W = 1200 - 900 = \mathbf{300 \text{ J}}$.
- b. $e = 300/1200 = \mathbf{0.25}$.
- c. $e_{\max} = 1 - 300/600 = 0.50$. Since $0.25 < 0.50$, the engine is **possible**.

Marking: 1 mark per part.

Question 5 Maximum efficiency (2 marks)

- a. $e_{\max} = 1 - 300/450 = \mathbf{0.333}$.
b. $W_{\max} = 300 \text{ J}$, so $Q_c = 900 - 300 = \mathbf{600 \text{ J}}$.

Marking: 1 mark each part.

Question 6 Entropy and heat flow (3 marks)

- a. Hot body: $-900/450 = \mathbf{-2.0 \text{ J/K}}$. Cold body: $+900/300 = \mathbf{+3.0 \text{ J/K}}$.
b. The total change is $+1.0 \text{ J/K}$, which is positive, so total entropy increases as the second law requires.

Marking: Part a: 1 mark per body. Part b: 1 mark.

Question 7 Compressing a gas quickly (2 marks)

- a. The cylinder is insulated and the process is fast, so $Q = 0$.
b. $\Delta U = Q + W$ with $Q = 0$ and $W > 0$, so ΔU is positive; for an ideal gas, a rise in U means a rise in T .

Marking: 1 mark each part.

Question 8 Engine or refrigerator? (2 marks)

- a. The gas does net work on the surroundings, so the net work done on the gas is **negative**.
b. Net work is done on the gas and heat is moved from cold to hot, so it represents a **refrigerator** (or heat pump).

Marking: 1 mark each part.