

Heat, work and engines on PV diagrams

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems practise the first law of thermodynamics, work from PV diagrams, the four basic gas processes, heat engines and entropy. They move from sign conventions and one-step calculations to cycles, efficiency limits and written arguments.

Use $\Delta U = Q + W$ with W as the work done on the gas, and convert every temperature to kelvin. AP questions reward clear reasoning, so state the sign of each term before you calculate.

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

Problem 1 Heat in, work out (easy)

Aarav in Pune watches a gas in a cylinder absorb 300 J of heat while it does 120 J of work on its surroundings.

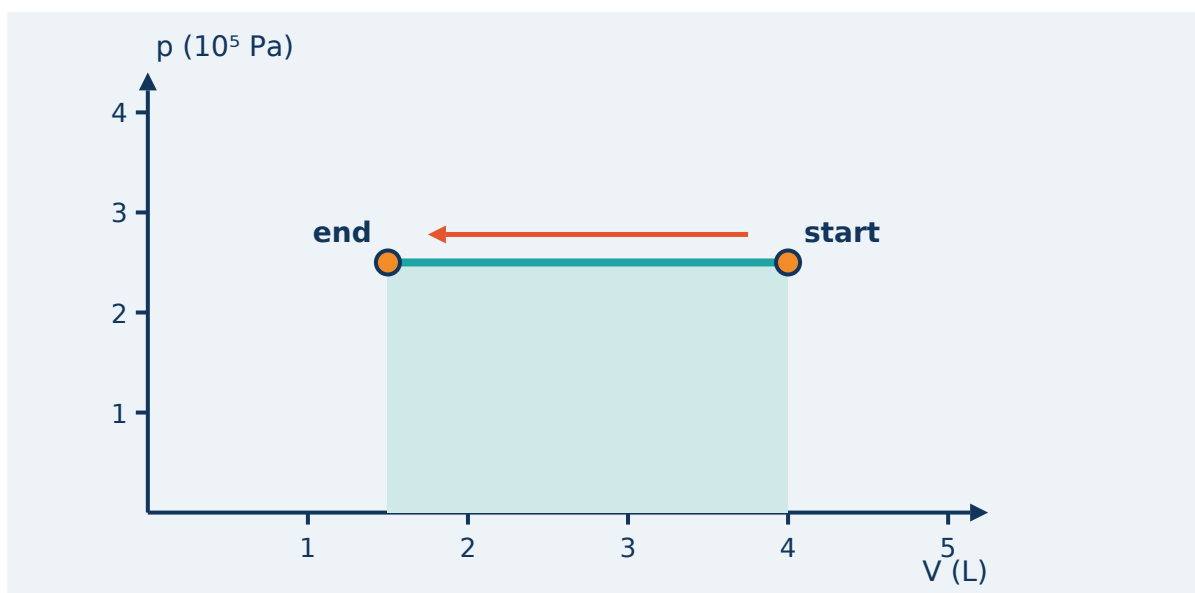
1. State the signs of Q and of W (work done on the gas).
2. Calculate the change in internal energy.

Problem 2 Constant pressure expansion (easy)

Chiamaka in Lagos lets a gas expand slowly at a constant pressure of 1.2×10^5 Pa from 2.0 L to 5.0 L.

1. Convert the volume change to m^3 .
2. Calculate the work done by the gas.
3. State the work done on the gas.

Problem 3 Compression on a graph (easy)



An isobaric compression from 4.0 L to 1.5 L.

The graph shows a gas compressed at constant pressure.

1. Read the initial and final volumes.
2. Calculate the work done on the gas.
3. State whether energy enters or leaves the gas as work.

Problem 4 Engine efficiency (easy)

An engine absorbs 2000 J of heat from its hot reservoir in one cycle and does 500 J of net work.

1. Calculate its efficiency.
2. Calculate the heat rejected to the cold reservoir.

Problem 5 Warming a monatomic gas (easy)

Bilal in Lahore warms 0.20 mol of a monatomic ideal gas by 50 K.

1. Write the expression for ΔU .
2. Calculate ΔU .
3. State whether ΔU depends on how the gas is warmed.

Problem 6 Rigid container (medium)

Mei in Singapore heats 0.50 mol of a monatomic ideal gas in a rigid container from 300 K to 420 K.

1. State the work done on the gas.
2. Calculate ΔU .
3. Calculate the heat added.

Problem 7 Slow squeeze in a water bath (medium)

Wanjiru in Nairobi compresses a gas very slowly while the cylinder sits in a large water bath,

so the temperature stays constant. The surroundings do 350 J of work on the gas.

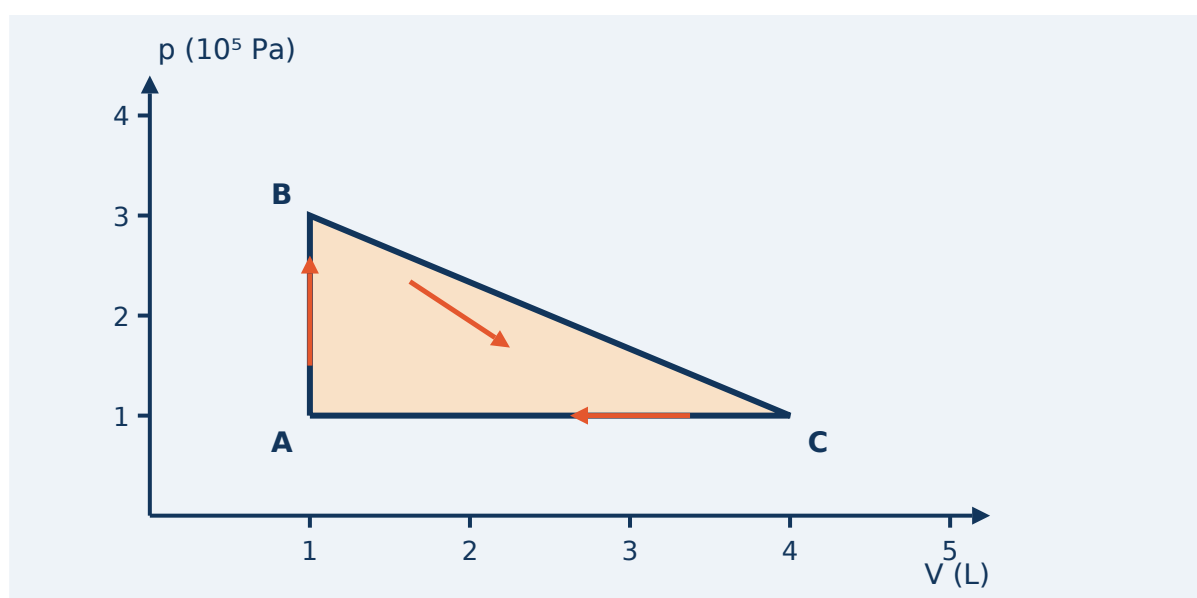
1. State ΔU .
2. Calculate Q .
3. Explain where the 350 J goes.

Problem 8 Quick pump stroke (medium)

A very fast pump stroke compresses 0.030 mol of air (treat it as monatomic) so quickly that no heat escapes. The surroundings do 15 J of work.

1. State Q for the process.
2. Calculate ΔU .
3. Calculate the temperature rise.

Problem 9 Triangular cycle (medium)



A triangular cycle ABCA.

A gas follows the cycle ABCA in the figure (A: 1.0 L, 1.0×10^5 Pa; B: 1.0 L, 3.0×10^5 Pa; C: 4.0 L, 1.0×10^5 Pa).

1. Calculate the area enclosed by the cycle.
2. State whether the net work is done by or on the gas.
3. State the net change in internal energy over one cycle.

Problem 10 Geothermal plant (medium)

A geothermal plant near Naivasha takes in 5.0×10^8 J of heat per cycle and delivers 1.8×10^8 J of work.

1. Calculate the efficiency.
2. Calculate the heat rejected.
3. Suggest what the rejected heat is carried away by.

Problem 11 Is this engine possible? (medium)

A designer in Texas claims an engine can reach an efficiency of 0.50 working between reservoirs at 550 K and 300 K.

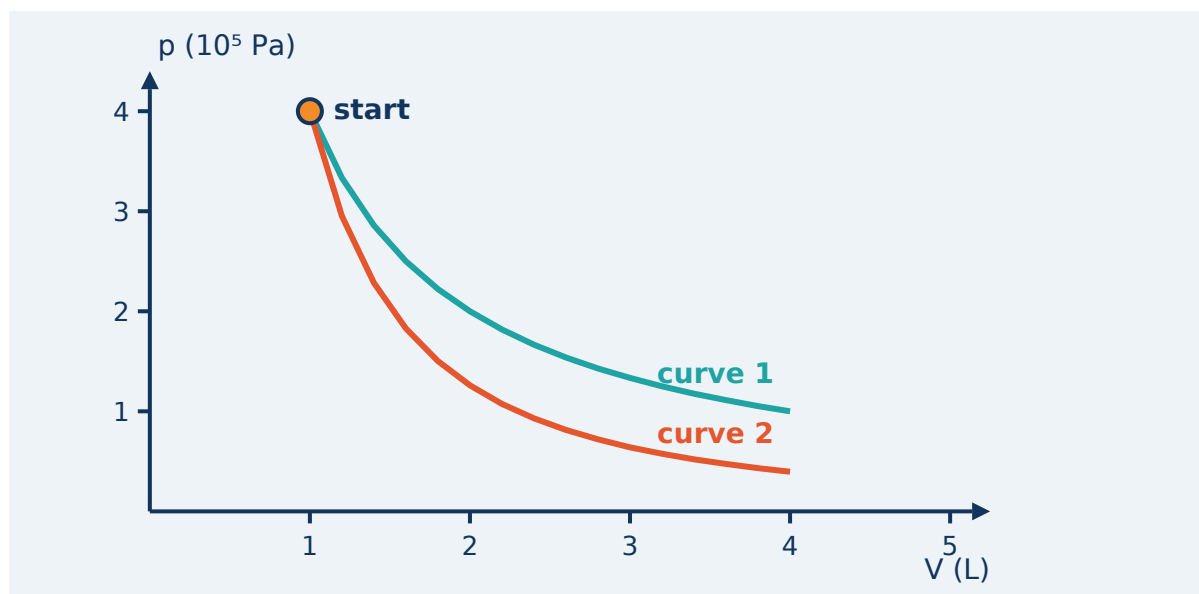
1. Calculate the Carnot efficiency for these temperatures.
2. Decide whether the claim is possible.
3. State what the Carnot efficiency tells you about real engines.

Problem 12 Entropy of heat flow (medium)

Emma in Leeds finds that 600 J of heat flows from a hot block at 400 K to a cold block at 300 K. Treat both temperatures as constant.

1. Calculate the entropy change of each block.
2. Calculate the total entropy change.
3. State what the sign of the total tells you.

Problem 13 Two expansions (medium)



Two expansions from the same state; one is isothermal and one is adiabatic.

A gas expands from the same starting state along curve 1 (isothermal) and along curve 2 (adiabatic).

1. Identify which curve is the isothermal expansion and justify your choice.
2. Compare the final temperatures.
3. Explain which expansion does more work on the surroundings.

Problem 14 Spot the error (medium)

A student writes: the gas absorbs 200 J of heat and expands, doing 80 J of work, so $\Delta U = Q + W = 200 + 80 = 280$ J.

1. Identify the error.
2. Give the correct value of ΔU .

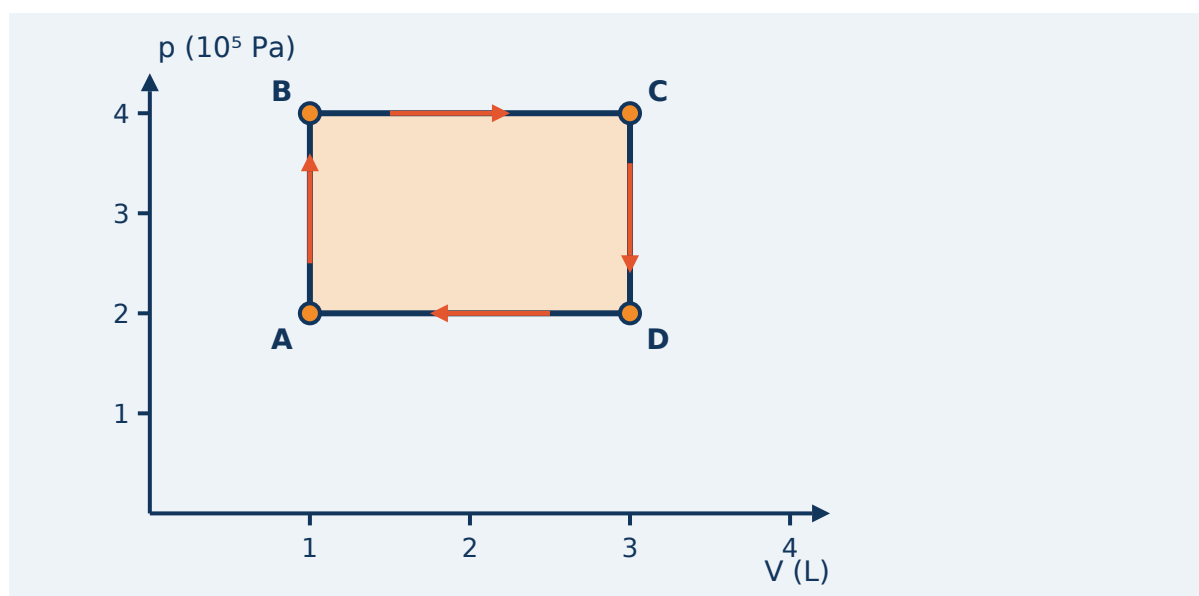
3. Explain what the 280 J would mean physically.

Problem 15 Constant pressure heating (medium)

Diego in Texas heats 0.040 mol of a monatomic ideal gas at constant pressure from 300 K to 450 K.

1. Calculate ΔU .
2. Calculate the work done by the gas using $p\Delta V = nR\Delta T$.
3. Calculate the heat added and the ratio $Q/\Delta U$.

Problem 16 Four-step engine cycle (hard)



A four-step cycle ABCD (monatomic ideal gas).

A monatomic ideal gas follows the cycle ABCD (A: 1.0 L, 2.0×10^5 Pa; B: 1.0 L, 4.0×10^5 Pa; C: 3.0 L, 4.0×10^5 Pa; D: 3.0 L, 2.0×10^5 Pa).

1. Calculate the net work per cycle.
2. Calculate the heat added in AB and in BC (use $\Delta U = 1.5\Delta(pV)$ and $Q = \Delta U - W$).
3. Calculate the efficiency, and compare it with the Carnot limit using the highest and lowest values of pV as stand-ins for temperature.

Problem 17 Adiabatic expansion (hard)

A monatomic ideal gas (0.10 mol) at 400 K expands so rapidly that no heat enters. It does 150 J of work on the surroundings.

1. State Q and W .
2. Calculate ΔU and the temperature change.
3. Calculate the final temperature.

Problem 18 Ocean thermal engine (hard)

An experimental engine uses warm surface water at 300 K and cold deep water at 277 K. Its real efficiency is 60% of the Carnot efficiency and it delivers 1.5 MW of power.

1. Calculate the Carnot efficiency.
2. Calculate the real efficiency.
3. Calculate the rate of heat input and the rate of heat rejection.

Problem 19 Melting ice and entropy (hard)

A juice seller in Accra melts 0.200 kg of ice at 0 °C (273 K) using heat from air at 20 °C (293 K). The latent heat of fusion of ice is 3.34×10^5 J/kg.

1. Calculate the heat absorbed.
2. Calculate the entropy change of the ice and of the air.
3. Show that the total entropy change is positive.

Problem 20 Two inventor claims (hard)

Two inventors make claims. Inventor 1: an engine draws 5.0 kJ per cycle from warm sea water at 300 K, delivers 5.0 kJ of work and rejects no heat. Inventor 2: an engine between 400 K and 300 K takes 1000 J per cycle and delivers 400 J of work.

1. Evaluate claim 1 using the first law and the second law in a short paragraph.
2. Calculate the largest work that claim 2's engine could deliver.
3. State whether claim 2 is possible.