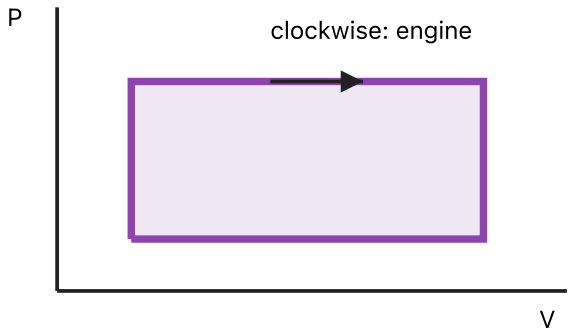
THERMO DAY 12: CYCLES & HEAT ENGINES

CED 9.4 · Skill 2.C · FRQ: MR · target: confusing net work with one leg's work

A CYCLE RETURNS TO ITS START

WARMUP **Trace the loop**

A gas follows the rectangular clockwise loop shown. Predict whether the gas delivers net work or requires net work.



Cycle: $\Delta U_{cycle} = 0 \Rightarrow Q_{net} = W_{by,net} = -W_{on,net}$

Clockwise loops deliver net work; counterclockwise loops require net work. The enclosed area is the magnitude.

QUICK A rectangular loop spans 100–240 kPa and 0.80–1.30 m³. Find the net work delivered per cycle.

ENGINE ENERGY ACCOUNTING

An engine absorbs Q_H from a hot reservoir, delivers W_{out}, and exhausts Q_C to a cold reservoir.

$$Q_H = W_{out} + Q_C \qquad e = \frac{W_{out}}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

WE DO An engine absorbs 900 J, exhausts 570 J, and repeats. Find work per cycle and efficiency.

YOU DO An engine is 28% efficient and absorbs 1.50 kJ per cycle. Find W_{out} and Q_C.

Efficiency is a fraction or percent, never an energy. A real cyclic heat engine must exhaust some energy to a colder reservoir.

CONNECT THE LOOP AND THE LEDGER

Leg	Q (J)	W_{by} (J)	ΔU (J)
A→B	+500	0	+500
B→C	+350	+250	+100
C→D	−420	0	−420
D→A	?	−130	?

COMPLETE Use $\sum \Delta U = 0$ to find the last leg, then calculate $W_{by,net}$, Q_{net}, and efficiency using total positive heat input.

Refrigerator direction: running the cycle counterclockwise requires work input to move energy from cold to hot.

PRACTICE

1. A clockwise rectangular cycle spans $\Delta P = 80\ \text{kPa}$, $\Delta V = 0.40\ \text{m}^3$. Find net work.

2. An engine absorbs 2.40 kJ and exhausts 1.65 kJ. Find work and efficiency.

3. A 35% efficient engine delivers 420 J. Find Q_H and Q_C.

4. A cycle has $W_{on,net} = +60\ \text{J}$. Is it operating as an engine or refrigerator? Find Q_{net}.

5. Explain why $\Delta U = 0$ for a complete cycle even though Q and W are not zero.