1. En motor mottar 4 kJ varmeenergi fra et 600 K varmereservoar, utfører en mengde arbeid og dumper deretter 2 kJ varmeenergi til et 200 K varmereservoar. Finn ut om denne motoren er en Carnot-motor eller ikke.

$Q_{in} = Q_H = 4.0$ kJ $\quad$ $T_H = 600$ K

$Q_{out} = Q_C = 2.0$ kJ $\quad$ $T_C = 200$ K

Carnot engine efficiency:

$$\eta_c = 1 - \frac{T_C}{T_H} = 1 - \frac{200\ K}{600\ K} = 0.667$$

Efficiency of this engine:

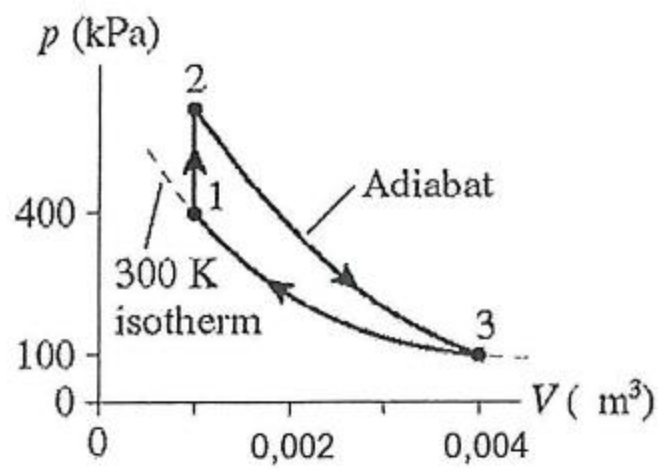
$$\eta = 1 - \frac{Q_C}{Q_H} = 1 - \frac{2.0\ kJ}{4.0\ kJ} = 0.50$$

This is not a carnot engine

2. en maskin følger n = 0.16 mol monatomic ideell gass en syklus som vist i figuren.

Start tilstanden er: P1 = 400 kPa, V1 = 0.001 m^3, T1 = 300 K
Steg 1 -> 2
Varme tilføres ved konstant volumet slik at trykk og temperatur stiger til P2, T2
Steg 2 -> 3
Gassen ekspanderer adiabatisk til en tilstand med: P3 = 100 kPa, V3 = 0.004 m^3, T3 = 300 K
Steg 3 -> 1
Kompresjon ved konstant temperatur til tilstanden 1.

monatomic ideell gass har γ = 5/3



a) Bruk adiabatlikningen PV$^\gamma$ = konstant til å beregne P2, Regn ut T2

The process 2 – 3 is adiabatic and we can use PV$^\gamma$ = konstant

$P_2V_2^\gamma = P_3V_3^\gamma$

Solve for P_2

$$P_2 = P_3\left(\frac{V_3}{V_2}\right)^\gamma = 100kPa\left(\frac{4.0\times 10^{-3}m^3}{1.0\times 10^{-3}m^3}\right)^{5/3} = 1008\ kPa$$

To find T2 we can use PV = nRT which holds at all points, and $V_1 = V_2$

$$\frac{P_1V_1}{P_2V_2} = \frac{nRT_1}{nRT_2}$$

Solve for T_2

$$T_2 = T_1\left(\frac{P_2}{P_1}\right) = 300\ K\left(\frac{1008\ kPa}{400\ kPa}\right) = 756\ K$$

b) Regn ut varmen Q_{12} fra 1 til 2, og Q_{31} fra 3 til 1

Q_{12} is the heat added to raise the pressure from P_1 to P_2
Apply the first law to this process:

$\Delta U_{12} = Q_{12} - W_{12}$

The work is zero, the process is constant volume and no work is done.
$W_{12} = 0$ and this gives $Q_{12} = \Delta U_{12}$

$$U = \frac{3}{2} nRT$$

$$\Delta U_{12} = \frac{3}{2} nR(T_2 - T_1) = \frac{3}{2}(0.16\ mol)\left(8.31\ {}^{J}/_{mol \cdot K}\right)(756\ K - 300\ K) = 910\ \mathrm{J}$$

$Q_{12} = \Delta U_{12} = 910$ J

3 – 1 is an isothermal process at $T_3 = T_1 = 300$K.
For an isothermal process: $\Delta U_{31} = 0$
Apply the first law to this process:

$\Delta U_{31} = Q_{31} - W_{31}$

$Q_{31} = W_{31}$

The work done is given by:

$$W = \int P dV = nRT \int_{V_3}^{V_1} \frac{1}{V} dV = nRT \ln\left(\frac{V_1}{V_3}\right)$$

$$Q_{31} = 0.16\ mol \cdot 8.31\ {}^{J}/_{mol \cdot K} \cdot 300\ K\ \ln\left(\frac{0.001\ m^3}{0.004\ m^3}\right) = -553\ \mathrm{J}$$

Q_{31} is negative, heat is removed to maintain constant temperature during compression.

c) Regn ut arbeidet W_{23} fra 2 til 3, og W_{31} fra 3 til 1
Work is done in processes 2 – 3 and 3 – 1.
For 2 – 3 this is an adiabatic process Q23 = 0
Apply the first law:

$\Delta U_{23} = Q_{23} - W_{23}$

$\Delta U_{23} = -W_{23}$ and $W_{23} = -\Delta U_{23}$

$\Delta U_{23} = 3/2\, nR(T_3 - T_2) = 3/2 \cdot 0.16 \text{ mol} \cdot (300 \text{ K} - 756 \text{ K}) = -910 \text{ J}$

$W_{23} = -\Delta U_{23} = 910 \text{ J}$

For 3 – 1 this is an isotherm process and the first law gives

$W_{31} = Q_{31}$

Which we calculated in part b)

$W_{31} = Q_{31} = -553 \text{ J}$

d) Finn maskinens virkningsgrad

The efficiency is given by

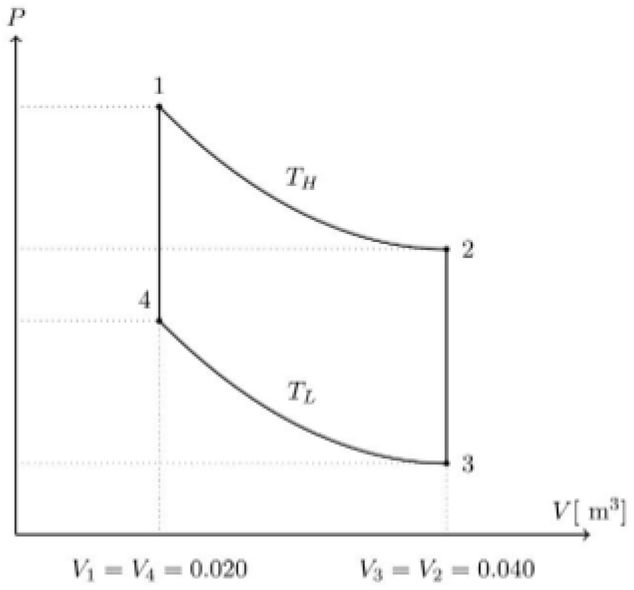
$$\eta = \frac{\text{work}}{Q_{\text{in}}}$$

Work = net work done in the cycle = $W_{23} + W_{31}$ = 910 J – 553 J = 357 J

Q_{in} = heat added = Q_{12} = 910 J

$$\eta = \frac{357 \text{ J}}{910 \text{ J}} = 0.389 = 39\%$$

3. Et PV-diagrammet er vist nedenfor. Kretsprosessen gjennomføres reversibelt. Prosessene 1→2 og 3→4 er isoterme. Systemet består av 1 mol av en to-atom ideell gass. Du får oppgitt at T2 = 600 K og T3 = 402 K. For to-atom ideell gass: U = 5/2 nRT



Fyll inn alle tallene i tabellen

Process 1 – 2 is an isothermal expansion from V_1 to V_2.
$\Delta U_{12} = 0$ and the first law $\Delta U = Q - W$ leads to $Q_{12} = W_{12}$

$$W_{12} = \int PdV = nRT \int_{V_1}^{V_2} \frac{1}{V} dV = nRT \ln\left(\frac{V_2}{V_1}\right)$$

$W_{12} =$ 1.0 mol · 8.314 J/mol K · 600 K · ln(0.04 m³/ 0.02 m³) = 3.46 kJ

$Q_{12} = W_{12}$ = 3.46 kJ

Process 2 – 3 is isochoric with ΔV = and $W_{23} = 0$
The first law leads to $\Delta U_{23} = Q_{23}$

Since it is a diatomic gas the internal energy is

$$U_{23} = \frac{5}{2} nRT$$

$$\Delta U_{23} = \frac{5}{2} nR\Delta T = \frac{5}{2} nR(T_3 - T_2)$$

$$\Delta U_{23} = \frac{5}{2} \cdot 1.0 \text{ mol} \cdot 8.314 \, {}^{\text{J}}\!/_{\text{mol K}} (402 \text{ K} - 600\text{K}) = \text{- } 4.12 \text{ kJ}$$

$Q_{23} = U_{23}$ = - 4.12 kJ

Process 3 – 4 is isothermal: $\Delta U_{34} = 0$ and $Q_{34} = W_{34}$

$$W_{34} = \int P dV = nRT \int_{V_3}^{V_4} \frac{1}{V} dV = nRT \ln\left(\frac{V_4}{V_3}\right)$$

$W_{34} =$ 1.0 mol · 8.314 J/mol K · 402 K · ln(0.02 m^3/ 0.04 m^3) = - 2.32 kJ

$Q_{34} = W_{34}$ = - 2.32 kJ

Process 4 – 1 is isochoric: $\Delta V = 0$ and $W_{41} = 0$
The first law leads to $\Delta U_{41} = Q_{41}$

$$\Delta U_{41} = \frac{5}{2} nR\Delta T = \frac{5}{2} nR(T_1 - T_4)$$

$$\Delta U_{41} = \frac{5}{2} \cdot 1.0 \text{ mol} \cdot 8.314 \,{}^{\text{J}}\!/_{\text{mol K}} (600 \text{ K} - 402\text{K}) = 4.12 \text{ kJ}$$

$Q_{41} = U_{41}$ = 4.12 kJ

	W [kJ]	Q [kJ]	ΔU [kJ]
1 -> 2 isotherm	3.46	3.46	0
2 -> 3 isochor	0	-4.12	-4.12
3 -> 4 isotherm	-2.32	-2.32	0
4 -> 1 isochor	0	4.12	4.12
Full cycle	1.14	1.14	0

Net work done in a full cycle = net heat input in a full cycle
Net change in internal energy = 0 for a full cycle