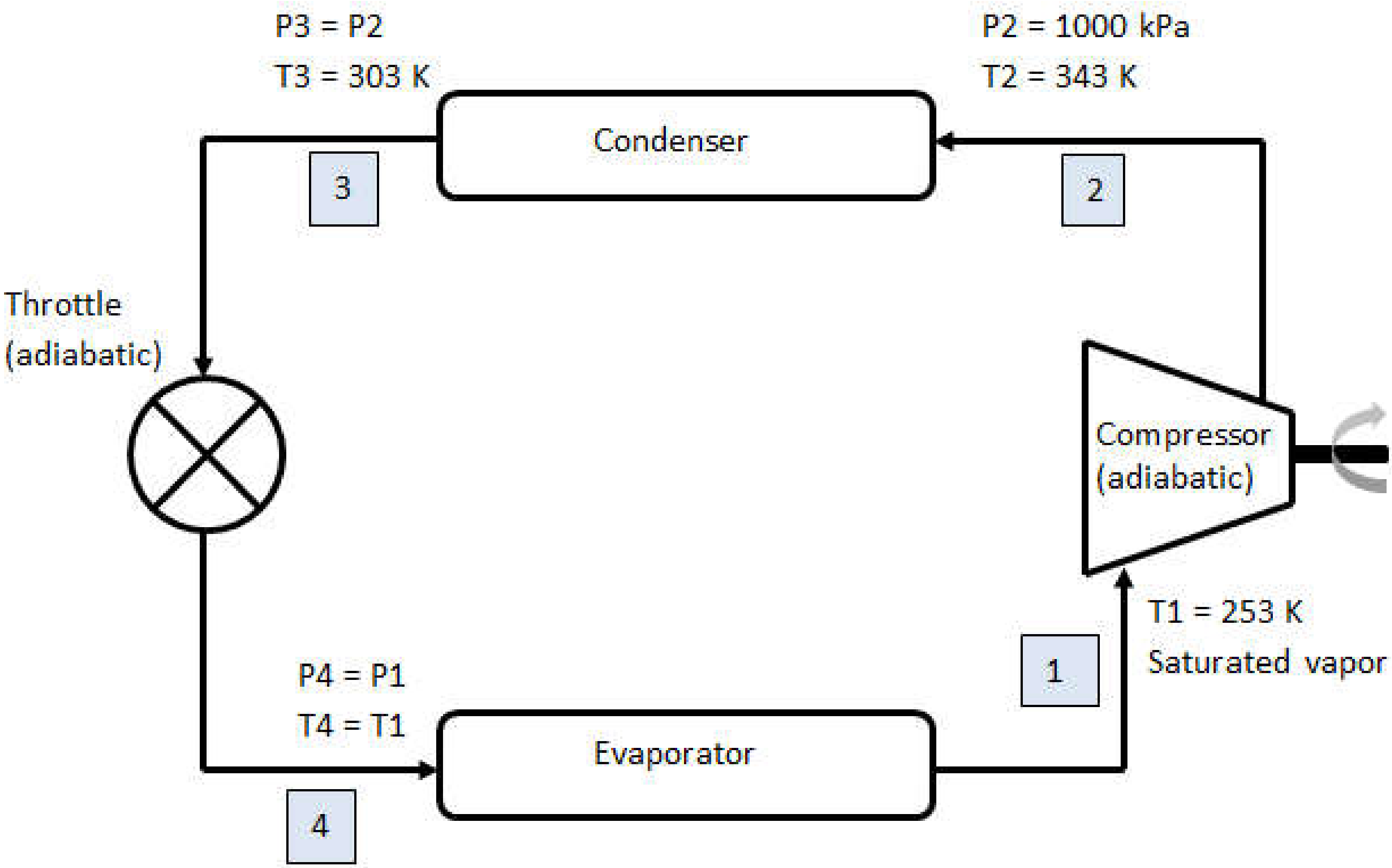
Analysis of a Vapor-Compression Refrigeration Cycle

Introduction

This application analyzes the following refrigeration cycle, and calculates the coefficient of performance.



Additionally, the thermodynamic cycle will be plotted on a pressure-enthalpy-temperature chart.

The compressor, condenser, throttle and evaporator are analyzed in sequence with this equation, a statement of the conservation of energy,

$$q - w = \Delta h + \Delta KE + \Delta PE$$

where

- w is the work done by the component
- ΔKE and ΔPE are the changes in kinetic and potential energy
- Δh is the change in specific enthalpy

• q is the heat transferred to the system

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> restart
> with(ThermophysicalData) :
  with(Units[Standard]) :
  with(plots) :
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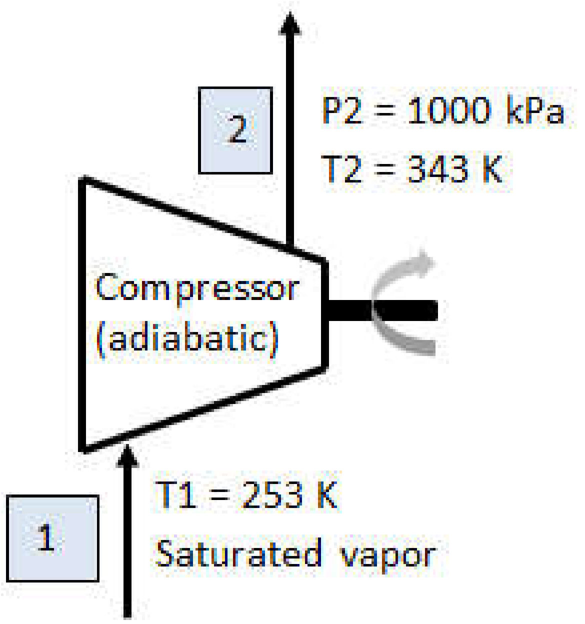
Compressor

Consider the energy flows in the compressor. For an adiabatic process, q = 0. Also ΔKE = 0 and ΔPE = 0. Hence -w = Δh



Enthalpies at points 1 and 2

> $P2 := 1000 \cdot 10^3 \text{Pa}$:

> h1 := Property(H, temperature = 253 K, Q = 1, R134a);

$$3.864615358\ 10^5\ \frac{\text{J}}{\text{kg}} \quad (2.1)$$

> h2 := Property(H, temperature = 343 K, pressure = P2, R134a);

$$4.518442441\ 10^5\ \frac{\text{J}}{\text{kg}} \quad (2.2)$$

The work done by the compressor (w)

> workCompressor := h1 − h2

$$-65382.7083\ \frac{\text{J}}{\text{kg}} \quad (2.3)$$

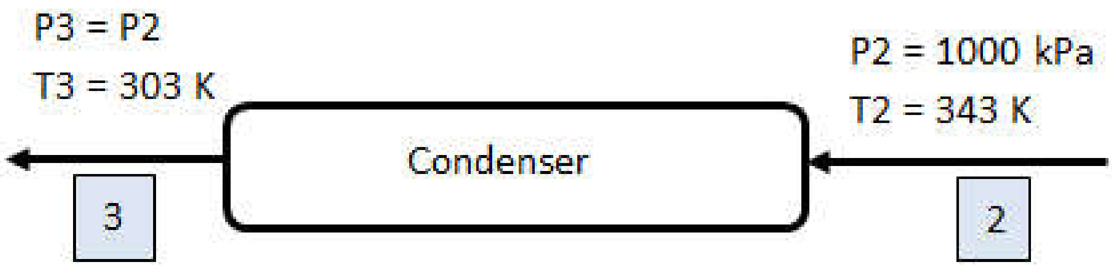
Pressure at point 1

> P1 := Property(P, temperature = 253 K, Q = 1, R134a)

$$P1 := 1.318769284\ 10^5\ \text{Pa} \quad (2.4)$$

Condenser

For the condenser, w = 0, ΔKE = 0 and ΔPE = 0. Hence q = Δh



Enthalpy at point 3

> h3 := Property(H, temperature = 303 K, pressure = P2, R134a)

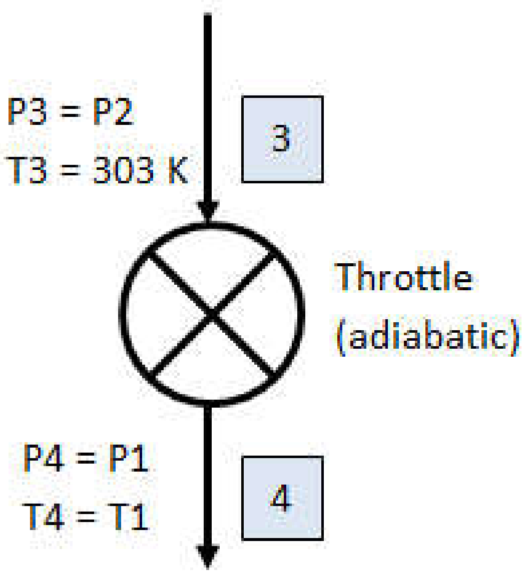
$$2.414995190\ 10^5\ \frac{J}{kg} \quad \textbf{(3.1}$$

> h3 − h2

$$-2.103447251\ 10^5\ \frac{J}{kg} \quad \textbf{(3.2}$$

Throttle

For the throttle, q = 0, w = 0, ΔKE = 0 and ΔPE = 0. Hence Δh = 0



Enthalpy at point 4

> h4 := h3

$$2.414995190\ 10^5\ \frac{J}{kg} \quad \textbf{(4.1}$$

Saturation pressure of R134a at 253 K

> P4 := P1

$$P4 := 1.318769284\ 10^5\ \text{Pa} \quad \textbf{(4.2}$$

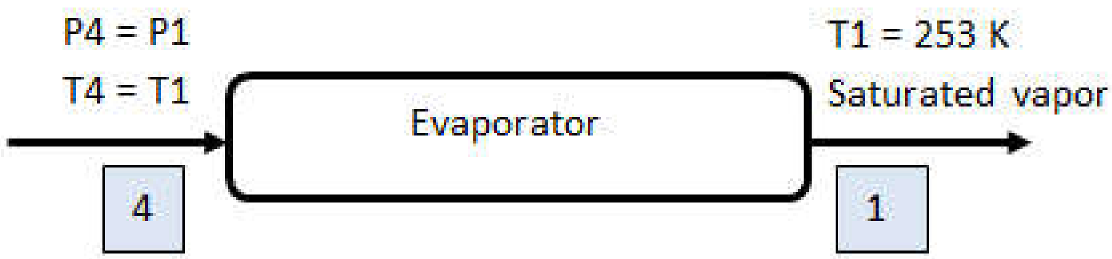
Quality at P = press4 and H = h4

> Property(Q, pressure = P4, H = h4, R134a)

$$0.3194910312 \quad \textbf{(4.3}$$

Evaporator

For the evaporator, w = 0, ΔKE = 0 and ΔPE = 0. Hence q = Δh



Heat extracted by evaporator

> heatEvaporator := h4 − h1

$$-1.449620168\ 10^5\ \frac{\text{J}}{\text{kg}} \quad \textbf{(5.1}$$

Coefficient of Performance

> $\frac{\text{heatEvaporator}}{\text{workCompressor}}$

$$2.217130807 \quad \textbf{(6.1}$$

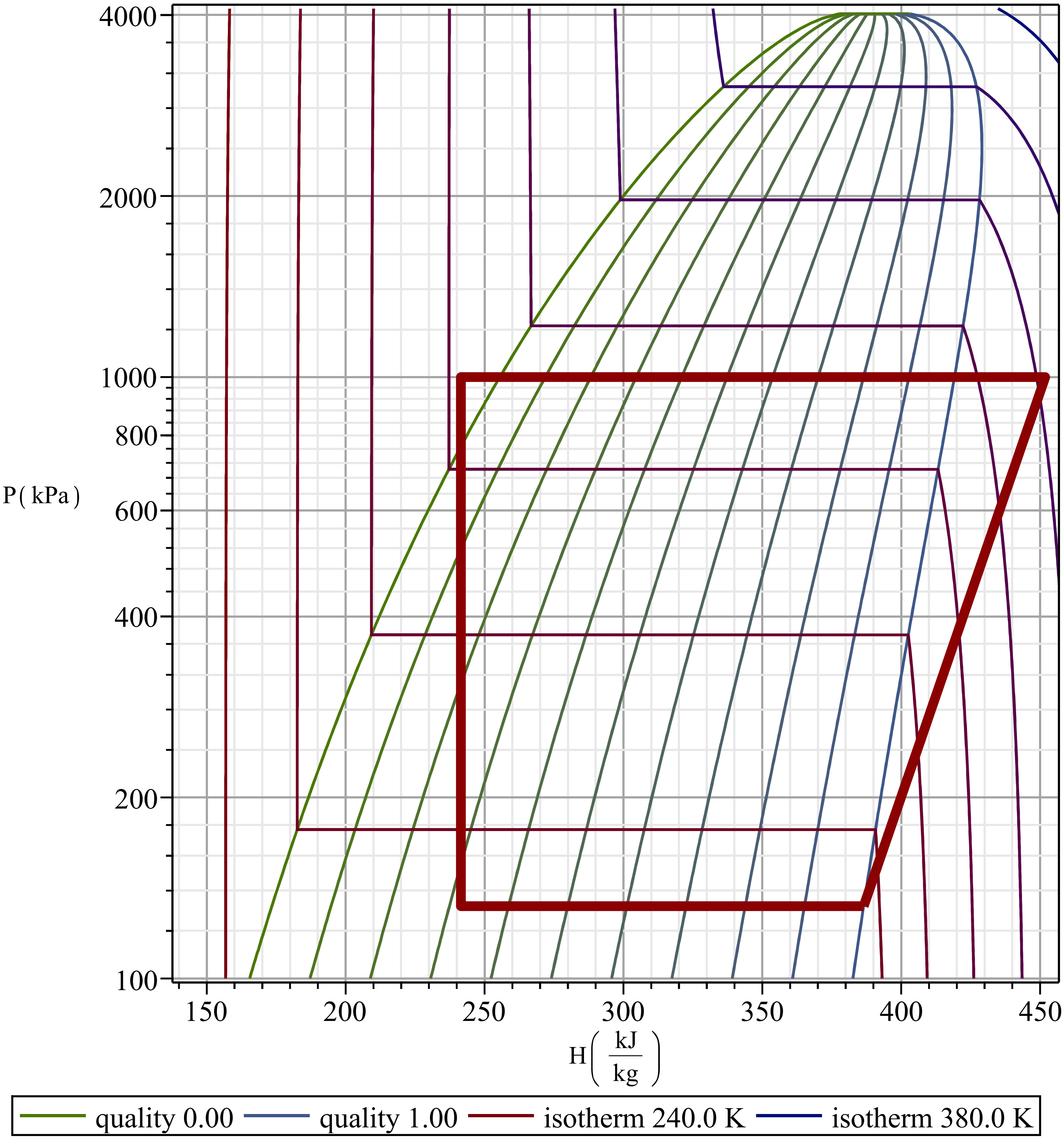
Plot the Refrigeration Cycle on a P-h-T Chart

> phtChart := PHTChart(R134a, 100 kPa ..4100 kPa) :

> pts := convert~([([h1, P1]), [h2, P2], [h3, P2], [h3, P4], [h1, P1]], unit_free) :

> cycle := pointplot(0.001 ·~pts, connect = true, color = "DarkRed", thickness = 5) :

> display(phtChart, cycle)



4000
2000
1000
800
600
400
200
100
P(kPa)
150
200
250
300
350
400
450
H(kJ/kg)
quality 0.00
quality 1.00
isotherm 240.0 K
isotherm 380.0 K