Thermodynamic_2026_1

Second Law_Entropy_S11_1
Mass control

NEDHER SANCHEZ RAMIREZ
NAUDY LOPEZ

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OBJECTIVE

Session 21-22: Apply the entropy balance in a closed system. Analize the entropy changes of processes with pure substances and ideal gases (Tds equation).

Recomendaciones generales:

- Leer antes de clase y entender los conceptos o preguntar si es necesario.
- Practicar bastante:
  - *Ejercicios de clase
  - *Asesorías
  - *Ejercicios del libro resueltos y los de final de capitulo
- Los quizzes virtuales y gradescope úsenlos para aprender de forma honesta (se puede inferir).
- Tengan grupos de estudio y apóyense mutuamente.
- Crear sus propias notas estudio y formulario.
- Son 4 horas de clase en la semana (asistir y ser puntuales, perder alguna es atrasarse mucho)
- Cada hora de clase son 3 horas de estudio por fuera mínimo.
- En la ppt de la semana 1 están todos los links claves para el curso.

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Thermodynamics _ Evaluation

COMPONENTE	%
EXAMEN PARCIAL	20
EXAMEN FINAL	30
C	50
APROBACIÓN: 11/20	

EXÁMENES	FECHAS
EXAMEN PARCIAL	(MAYO 11)
EXAMEN FINAL	(JULIO 6)

EXAMEN PARCIAL : Todos los temas vistos hasta la semana 6.
EXAMEN FINAL: Todos los temas vistos hasta la semana 15

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Thermodynamics _ Evaluation

COMPONENTE	%
PARCIAL	20
FINAL	30
C	50
APROBACIÓN: 11/20	

SEMANA 1	TAREA VIRTUAL	SE CALIFICA AUTOMATICO NO NECESITA PROCEDIMIENTO
SEMANA 2	TAREA VIRTUAL	
SEMANA 3	TAREA VIRTUAL	.
SEMANA 4	**TAREA INDIVIDUAL 1** + EVALUACION_ AULA1	TAREA INDIVIDUAL: Esta parte incluye subir un archivo con la solución EVALUACION_ AULA: SEMANAS 1-2
SEMANA 5	TAREA VIRTUAL+ EVALUACION_ AULA2	EVALUACION_ AULA: SEMANAS 1-3
SEMANA 6	TAREA VIRTUAL**+TAREA INDIVIDUAL 2**	
SEMANA 7	TAREA VIRTUAL+ EVALUACION_ AULA3	EVALUACION_ AULA: SEMANAS 1-6
SEMANA 8	**PARCIAL**	
SEMANA 9	EVALUACION_ AULA4+**TAREA INDIVIDUAL 3 +Tarea grupal 1**	EVALUACION_ AULA: SEMANAS 1-8
SEMANA 10	TAREA VIRTUAL	
SEMANA 11	TAREA VIRTUAL	
SEMANA 12	TAREA VIRTUAL+ EVALUACION_ AULA5	EVALUACION_ AULA: SEMANAS 1-11
SEMANA 13	TAREA VIRTUAL**+TAREA INDIVIDUAL 4 + Tarea grupal 2**	
SEMANA 14	EVALUACION_ AULA6	EVALUACION_ AULA : SEMANAS 1-13
SEMANA 15		
SEMANA 16	**FINAL**	

*LAS TAREAS VIRTUALES O LOS GRADESCOPE (TAREA INDIVIDAL) **se abren lunes 2pm y se cierran sábado media noche. La tarea virtual se presenta hasta un máximo de 3 veces.**

EVALUACION_ AULA: es un quiz de 20 min aprox. en aula.

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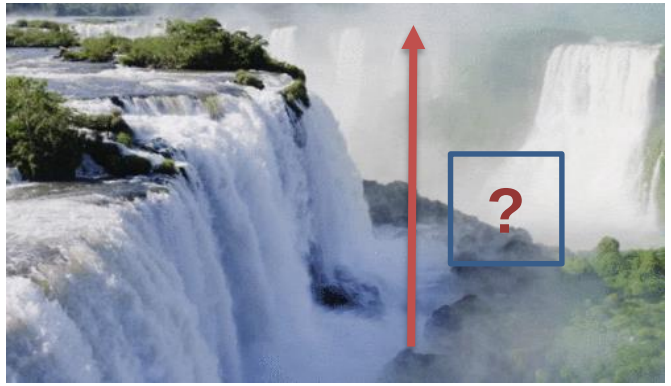

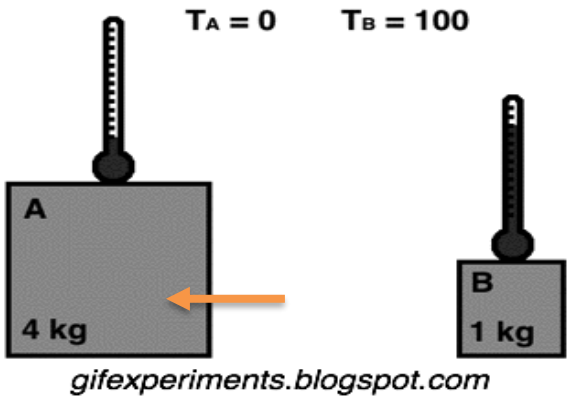

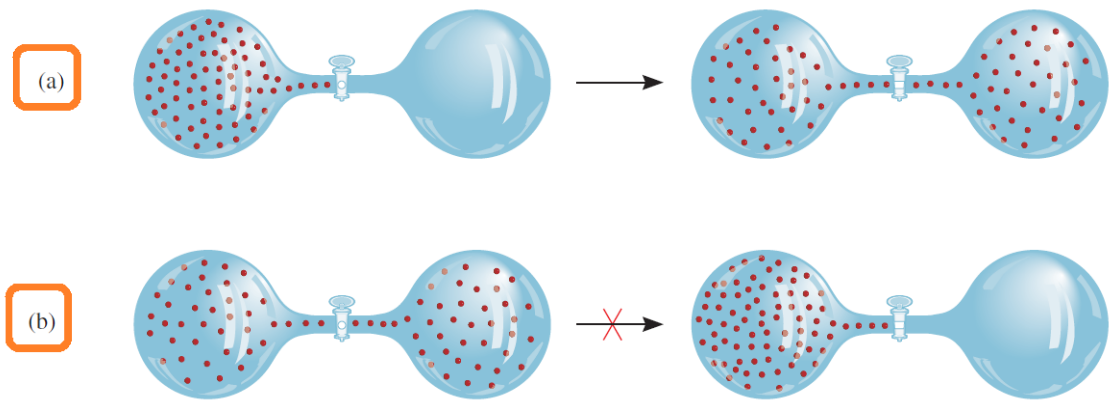

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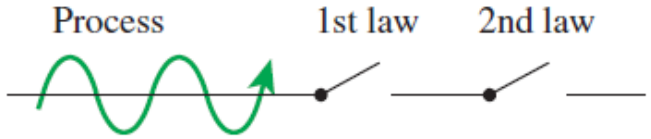
Aspects of the Second Law

1. The first law places no restriction on the direction of a process, but satisfying the first law does not ensure that the process can actually occur. This is remedied by introducing another general principle, **the second law of thermodynamics.**



https://www.youtube.com/watch?v=bCkHpEY9Mdk

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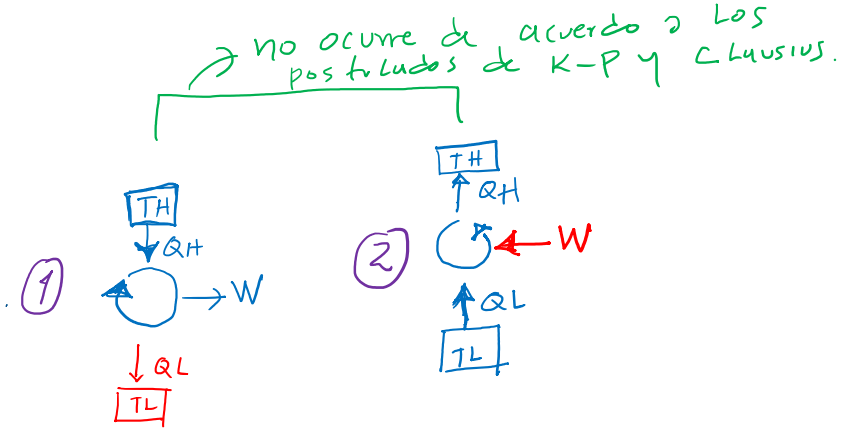
Aspects of the Second Law

2. Predicting the direction of processes *[possible or not…]*.



3. Determining the best theoretical performance of cycles, engines, and other devices *[COP or η,]*.

$\eta = 1 - \frac{|Q_L|}{|Q_H|}$ $\quad cop = \frac{|Q_L|}{|W|}$

Límites puestos por Carnot:

$\eta = 1 - \frac{T_L}{T_H}$, $cop = \frac{T_L}{T_H - T_L}$

> Forma mas cuantitativa de aplicar la 2da Ley.

Real > ideal ⇒ Imposible

Real = ideal ⇒ Reversible

Real < ideal ⇒ Irreversible (posible)
↳ hay fricción ETC

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Aspects of the Second Law

3. Determining the best theoretical performance of cycles, engines, and other devices *[COP or η,]*.

$\eta = 1 - \frac{|Q_L|}{|Q_H|}$ $\quad COP = \frac{|Q_L|}{|W|}$

Limites puestos por carnot:

$\eta = 1 - \frac{T_L}{T_H}$, $COP = \frac{T_L}{T_H - T_L}$

> Forma mas cuantitativa de aplicar La 2da Ley.

4. Evaluating quantitatively the factors that preclude the attainment of the best theoretical performance level [Friction, finite difference of T ...]

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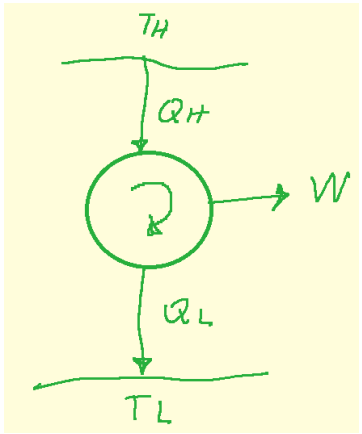
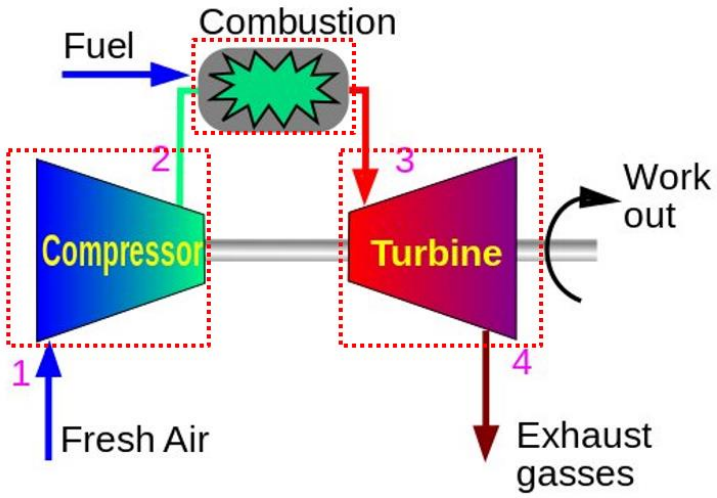
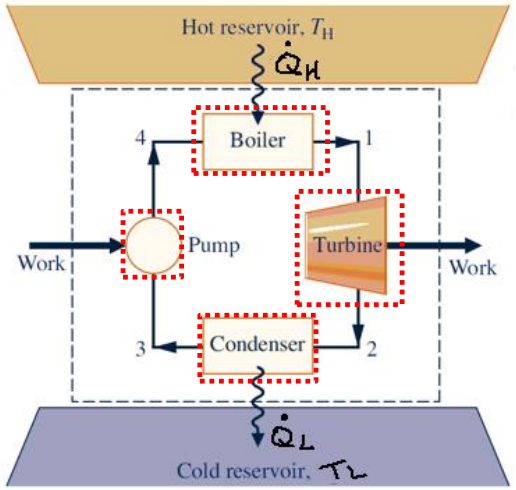
Aspects of the Second Law

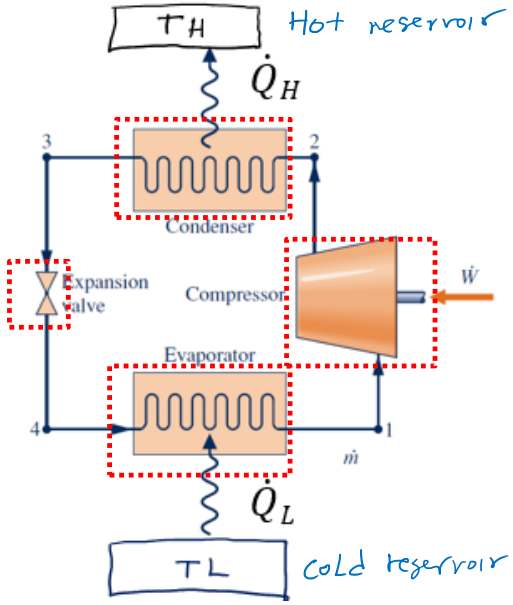
5. The second law also affirms that energy has **quality** as well as quantity (If we analyze a heat engine, the higher T_H is, the bigger the percentage of Q_H that can be converted into W, that is, there will be less entropy generated, so a Q_H that comes out of a source at a higher T_H has more quality

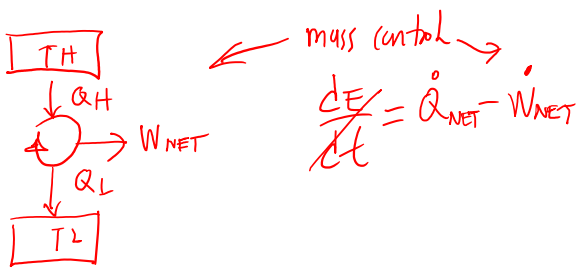


What is the difference between these 3 arrangements?



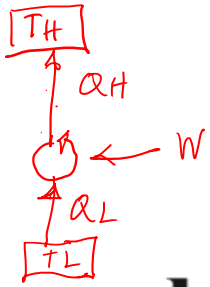






mass control

$\frac{dE}{dt} = \dot{Q}_{NET} - \dot{W}_{NET}$



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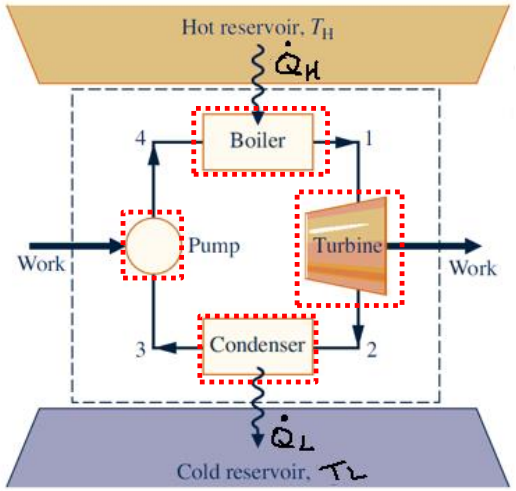
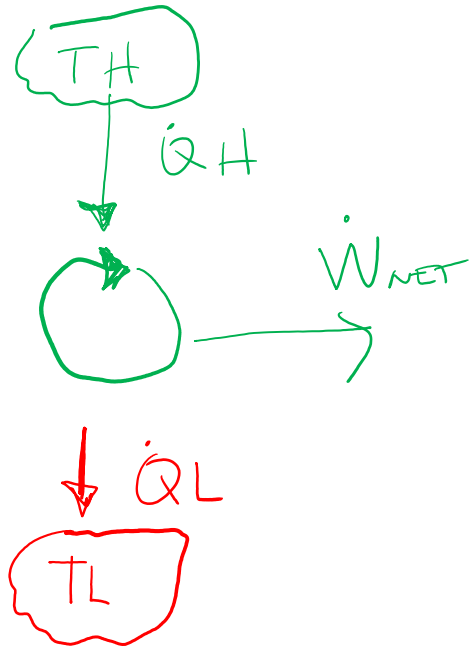
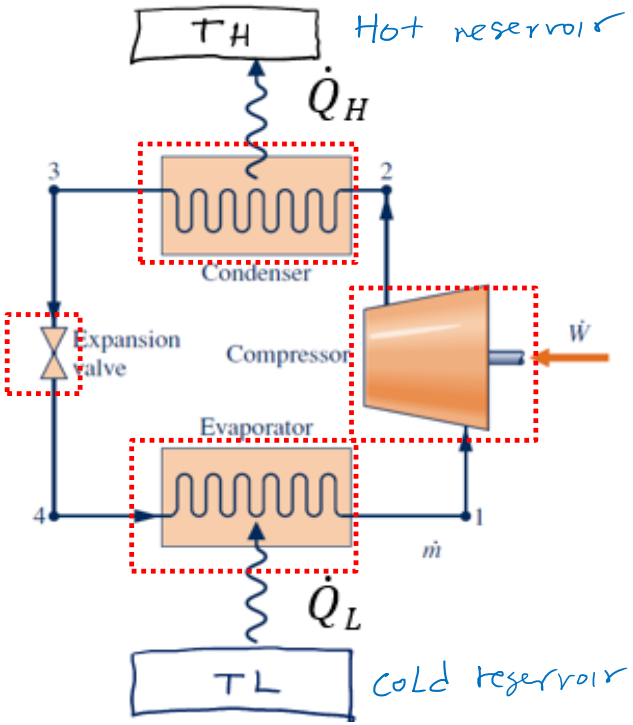
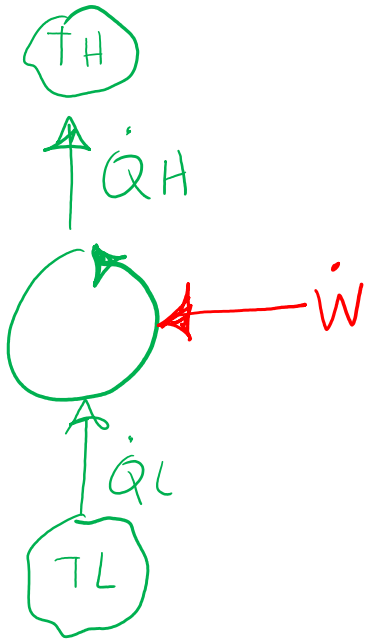
KELVIN – PLANK





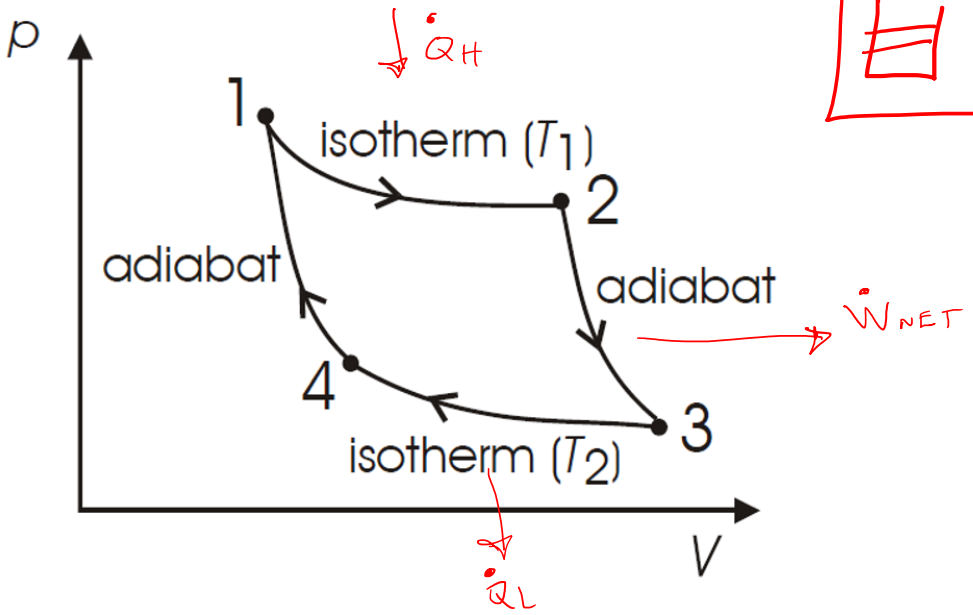
CLAUSIUS



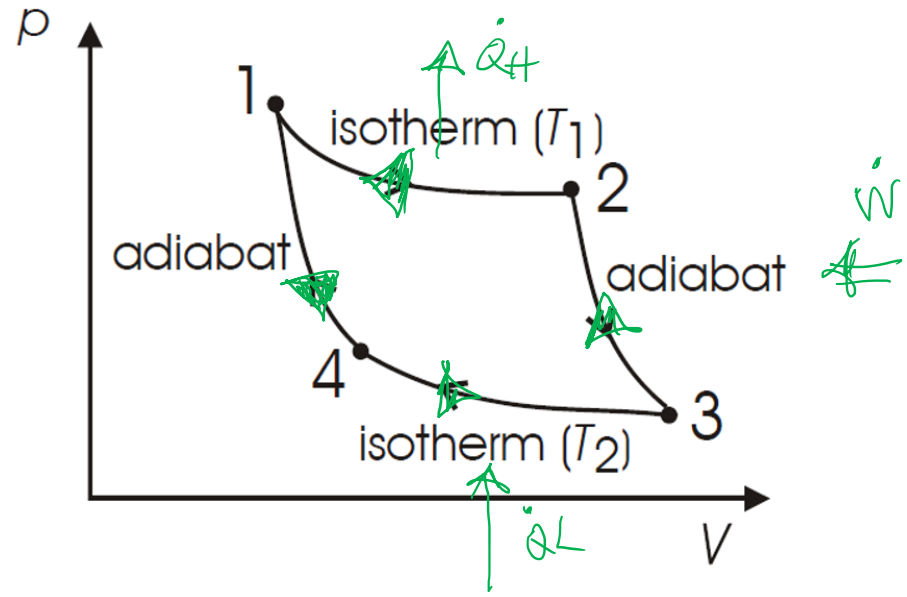


CARNOT_Ideal gas (W_{rev})

All paths are reversible



All paths are reversible



Power or Refrigeration cycle?

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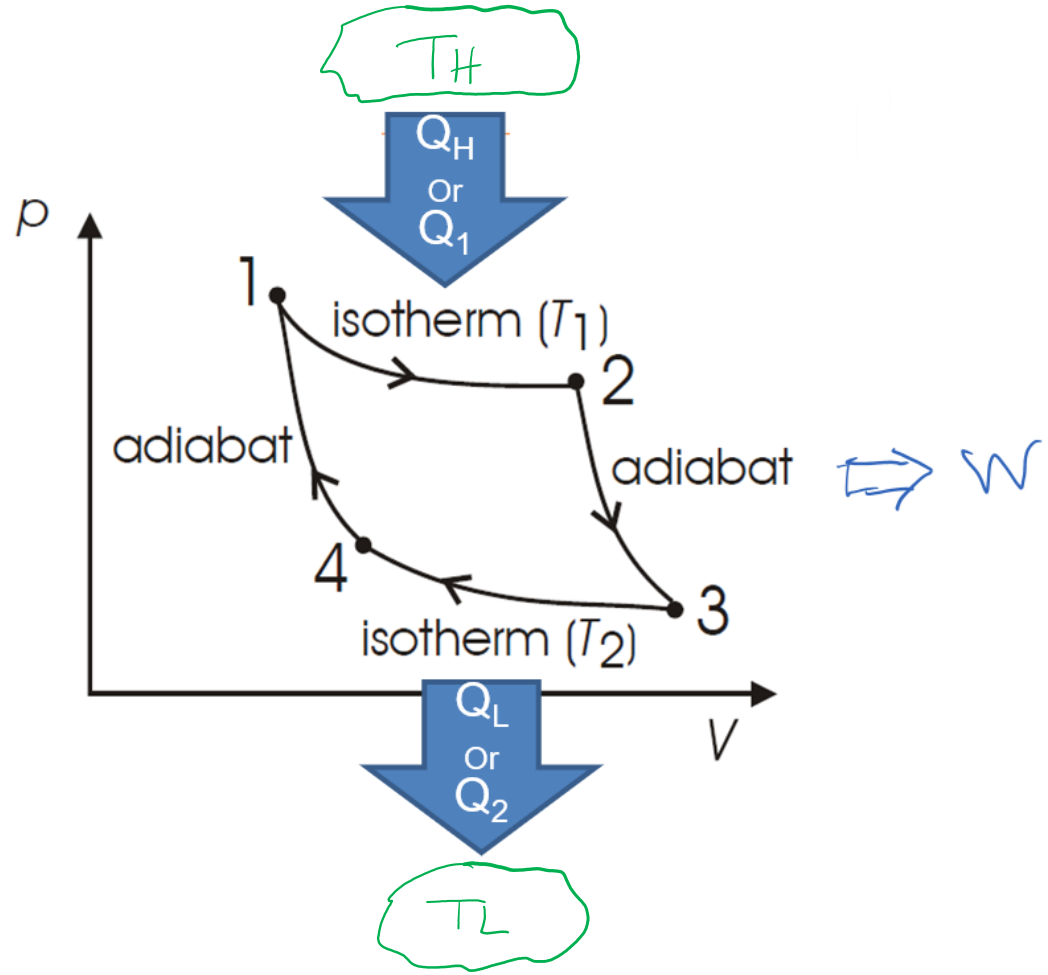
THE CARNOT CYCLE AS **HEAT ENGINE….MASS CONTROL**

All paths are reversible



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Carnot cycle for an ideal gas

_ CONTROL MASS_ 1mol

$\Delta U = Q - W$; $PV = nRT$, cte isot.

$1 \rightarrow 2$ $\quad \Delta U = 0;\ Q1 = \ w_1 = \int_1^2 pdV = \bar{R} T_1 \ln\left(\frac{V_2}{V_1}\right)$

($\Delta U' = Q - W'$)

$2 \rightarrow 3$ $\quad Q = 0;\ -w_1' = C_V (T_2 - T_1)$

Rev. adiabat $\Rightarrow$ $\left(\frac{T_2}{T_1}\right) = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$

$3 \rightarrow 4$ $\quad \Delta U = 0;\ Q2 = \ w_2 = \int_3^4 pdV = \bar{R} T_2 \ln\left(\frac{V_4}{V_3}\right)$

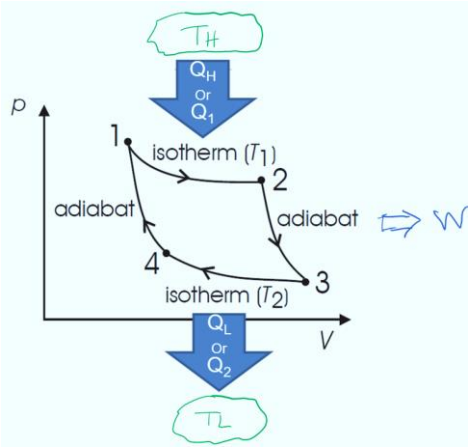
$4 \rightarrow 1$ $\quad Q = 0;\ -w_2' = C_V (T_1 - T_2)$

Rev. adiabat $\Rightarrow$ $\left(\frac{T_1}{T_2}\right) = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$

$$\frac{Q2}{Q1} = \frac{T_2 \ln(V_4/V_3)}{T_1 \ln(V_2/V_1)}$$

$$\left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{T_2}{T_1}\right) = \left(\frac{V_2}{V_3}\right)^{\gamma-1} \Rightarrow \left(\frac{V_4}{V_3}\right) = \left(\frac{V_1}{V_2}\right) \Rightarrow \boxed{\frac{Q2}{Q1} = -\frac{T_2}{T_1}}$$

T1ln(V2/V1) = -T1ln(V1/V2)



$$\frac{Q_L}{Q_H} = -\frac{T_L}{T_H}$$

$$\frac{Q_H}{T_H} + \frac{Q_L}{T_L} = 0$$

$$\frac{|Q_H|}{T_H} - \frac{|Q_L|}{T_L} = 0$$

$$\frac{|Q_L|}{|Q_H|} = \frac{T_L}{T_H}$$

$$\eta_{th} = 1 - \frac{|Q_L|}{|Q_H|}$$

$$\eta_{th,\,ideal} = 1 - \frac{T_L}{T_H}$$

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1. THE REVERSE CARNOT CYCLE_CONTRIBUTION

Efficiency of a Heat Engine:

$$\eta = \frac{|Q_H| - |Q_L|}{|Q_H|} = 1 - \left|\frac{Q_L}{Q_H}\right|$$

$$\eta_{ideal} = 1 - \frac{T_L}{T_H}$$

$\eta_{real} > \eta_{ideal} \rightarrow$ Imposible

$\eta_{real} = \eta_{ideal} \rightarrow$ Reversible

$\eta_{real} < \eta_{ideal} \rightarrow$ Irreversible, posible

COP of a refrigerator:

$$COP_R = \beta_R = \frac{|Q_L|}{|W|} = \frac{|Q_L|}{|Q_H| - |Q_L|}$$

$$COP_R^{ideal} = \frac{|T_L|}{|T_H| - |T_L|}$$

↳ Igual para COP

COP of a heat pump:

$$COP_{HP} = \beta_{HP} = \frac{|Q_H|}{|W|} = \frac{|Q_H|}{|Q_H| - |Q_L|}$$

$$COP_{HP}^{ideal} = \frac{|T_H|}{|T_H| - |T_L|}$$

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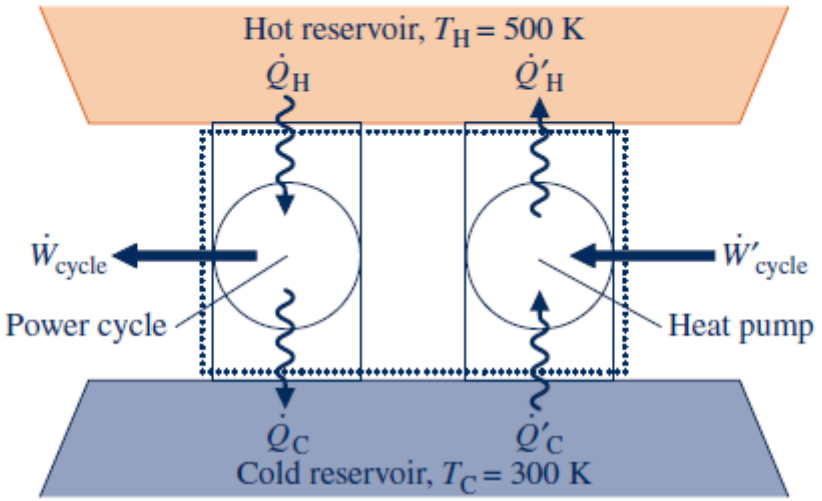
EXERCISE 7.2

A system consisting of a power cycle and a heat pump cycle, each operating between hot and cold reservoirs whose temperature are 500 K and 300 K, respectively. All energy transfers are positive in the directions of the arrows. The accompanying table provides two sets of steady-state data, in kW. For each set of data, determine if the system is operating in accord with the first and second laws of thermodynamics..

	Power cycle			Heat pump cycle		
	$\lvert\dot{Q}_H\rvert$	$\lvert\dot{Q}_C\rvert$	$\lvert\dot{W}_{cycle}\rvert$	$\lvert\dot{Q}'_H\rvert$	$\lvert\dot{Q}'_C\rvert$	$\lvert\dot{W}'_{cycle}\rvert$
(a)	60	40	20	80	60	20
(b)	120	80	40	100	80	20



In order to satisfy the first and the second law, the three cycles (power cycle, heat pump and the overall system) must meet the energy balance and must have less efficiency than a Carnot cycle operating between 500K and 300K.

a) Power cycle

First law

$$\dot{Q}_H = \dot{Q}_C + \dot{W}_{cycle}$$

$$60 = 40 + 20$$

$$60 = 60 \qquad \textbf{\textit{Correct}}$$

Second law

$$\eta_{Carnot} = 1 - \frac{T_C}{T_H} = 1 - \frac{300}{500} = 0.4$$

$$\eta_a = \frac{\dot{W}_{cycle}}{\dot{Q}_H} = \frac{20}{60} = 0.33 < \eta_{Carnot} \qquad \textbf{\textit{Correct}}$$

a) Heat pump cycle

First law

$$\dot{Q}'_H = \dot{Q}'_C + \dot{W}'_{cycle}$$

$$80 = 60 + 20$$

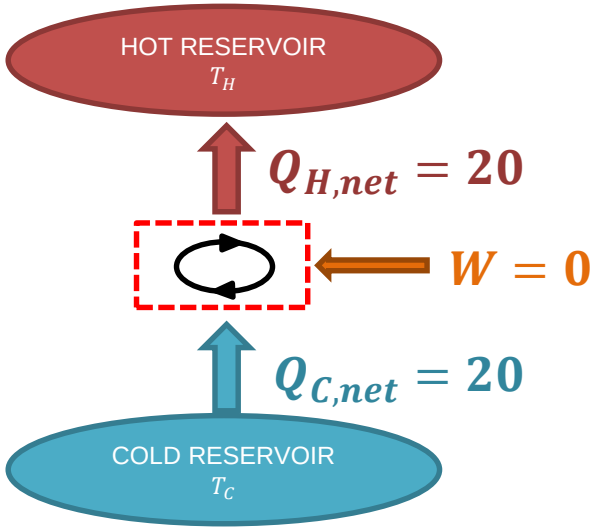
$$80 = 80$$ ***Correct***

Second law

$$\beta_{Carnot} = \frac{T_H}{T_H - T_C} = \frac{500}{500 - 300} = 2.5$$

$$\beta_a = \frac{\dot{Q}'_H}{\dot{W}'_{cycle}} = \frac{80}{20} = 4 > \beta_{Carnot}$$ ***Incorrect***

a) Overall cycle can be evaluated as a heat pump



First law

$$\dot{Q}_{H,net} = \dot{Q}_{C,net} + \dot{W}_{cycle,net}$$

$$20 = 20 + 0$$

$$20 = 20$$ ***Correct***

Second law

$$\beta_{a,net} = \frac{\dot{Q}_{H,net}}{\dot{W}_{cycle,net}} = \frac{20}{0} = \infty > \beta_{Carnot}$$ ***Incorrect***

b) Power cycle

First law

$$\dot{Q}_H = \dot{Q}_C + \dot{W}_{cycle}$$

$$120 = 80 + 40$$

$$120 = 120$$ ***Correct***

Second law

$$\eta_{Carnot} = 1 - \frac{T_C}{T_H} = 1 - \frac{300}{500} = 0.4$$

$$\eta_b = \frac{\dot{W}_{cycle}}{\dot{Q}_H} = \frac{40}{120} = 0.33 < \eta_{Carnot}$$ ***Correct***

b) Heat pump cycle

First law

$$\dot{Q}'_H = \dot{Q}'_C + \dot{W}'_{cycle}$$

$$100 = 80 + 20$$

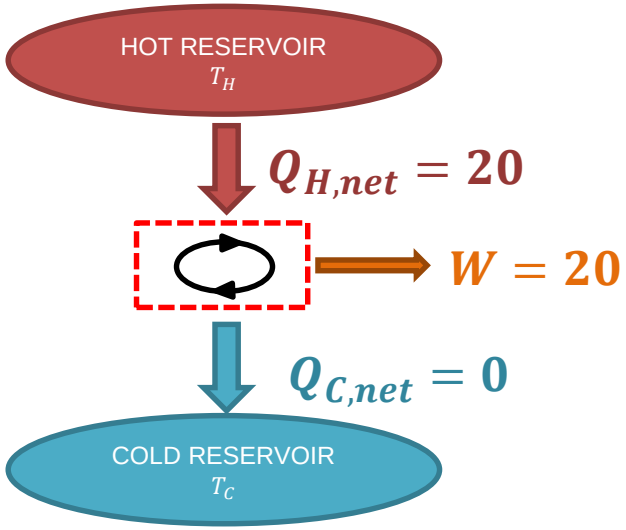
$$100 = 100$$ ***Correct***

Second law

$$\beta_{Carnot} = \frac{T_H}{T_H - T_C} = \frac{500}{500 - 300} = 2.5$$

$$\beta_b = \frac{\dot{Q}'_H}{\dot{W}'_{cycle}} = \frac{100}{20} = 5 > \beta_{Carnot}$$ ***Incorrect***

b) Overall cycle can be evaluated as a heat engine



First law

$$\dot{Q}_{H,net} = \dot{Q}_{C,net} + \dot{W}_{cycle,net}$$

$$20 = 0 + 20$$

$$20 = 20$$ ***Correct***

Second law

$$\eta_{b,net} = \frac{\dot{W}_{cycle,net}}{\dot{Q}_{H,net}} = \frac{20}{20} = 1 > \eta_{Carnot}$$ ***Incorrect***

Carnot cycle for an ideal gas

_ CONTROL MASS_

Carnot cycle for an ideal gas

_ CONTROL MASS_ 1mol

$\Delta U = Q - W$

$PV = nRT$ cte isot.

$1 \rightarrow 2 \quad \Delta U = 0; \quad Q1 = \quad w_1 = \int_1^2 p dV = \bar{R} T_1 \ln\left(\frac{V_2}{V_1}\right)$

$\Delta U = Q - W$

$2 \rightarrow 3 \quad Q = 0; \quad -w_1' = C_V (T_2 - T_1)$

Rev. adiabat $\Rightarrow \quad \left(\frac{T_2}{T_1}\right) = \left(\frac{V_2}{V_3}\right)^{\gamma - 1}$

$3 \rightarrow 4 \quad \Delta U = 0; \quad Q2 = \quad w_2 = \int_3^4 p dV = \bar{R} T_2 \ln\left(\frac{V_4}{V_3}\right)$

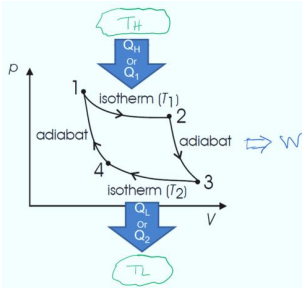
$4 \rightarrow 1 \quad Q = 0; \quad -w_2' = C_V (T_1 - T_2)$

Rev. adiabat $\Rightarrow \quad \left(\frac{T_1}{T_2}\right) = \left(\frac{V_4}{V_1}\right)^{\gamma - 1}$

$\frac{Q2}{Q1} = \frac{T_2 \ln(V_4/V_3)}{T_1 \ln(V_2/V_1)}$

$\left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{T_2}{T_1}\right) = \left(\frac{V_2}{V_3}\right)^{\gamma-1} \Rightarrow \left(\frac{V_4}{V_3}\right) = \left(\frac{V_1}{V_2}\right) \Rightarrow \boxed{\frac{Q2}{Q1} = -\frac{T_2}{T_1}}$

T1ln(V2/V1) = -T1ln(V1/V2)



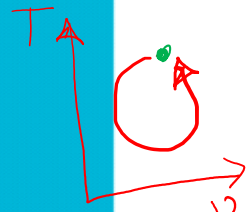
$$\frac{Q_L}{Q_H} = -\frac{T_L}{T_H}$$

$$\frac{Q_H}{T_H} + \frac{Q_L}{T_L} = 0$$

$$\frac{|Q_H|}{T_H} - \frac{|Q_L|}{T_L} = 0$$

Entropía

$$\oint \frac{\delta Q_{rev}}{T} = 0$$



$\oint du = 0$

$\oint dh = 0$

$\oint dv = 0$

$\Rightarrow \frac{\delta Q_{rev}}{T}$ es una propiedad de estado como u, h, v. La llamaremos "s"

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$$\oint \frac{\delta Q_{rev}}{T} = 0 \qquad dS$$

S → Entropy

$$\oint du = 0$$

$$\oint dh = 0$$

$$\oint dv = 0$$

ciclos ✓

cerrado { Est ✓
Abierto { Transitr ✓

La entropía (S) nos permitirá hacer balances que nos permiten aplicar la 2da ley de forma cuantitativa tanto en ciclos como en procesos y usarlo en { masa de control / V. de control { E. estacionario / transiente

Entropy – State function

Tanto el sistema, como los alrededores, vuelven a su estado original.

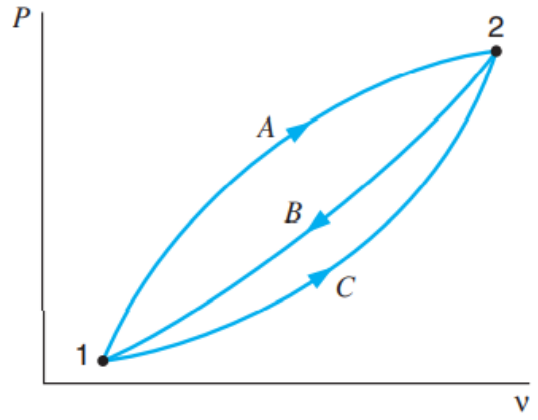


FIGURE 6.4 Two reversible cycles demonstrating that entropy is a property of a substance.

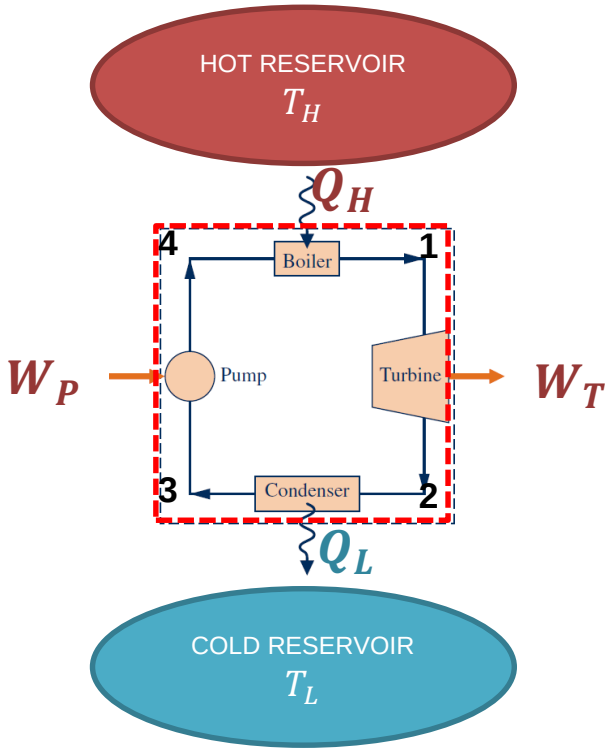
$$\oint \frac{\delta Q}{T} = 0 = \int_1^2 \left(\frac{\delta Q}{T}\right)_A + \int_2^1 \left(\frac{\delta Q}{T}\right)_B$$

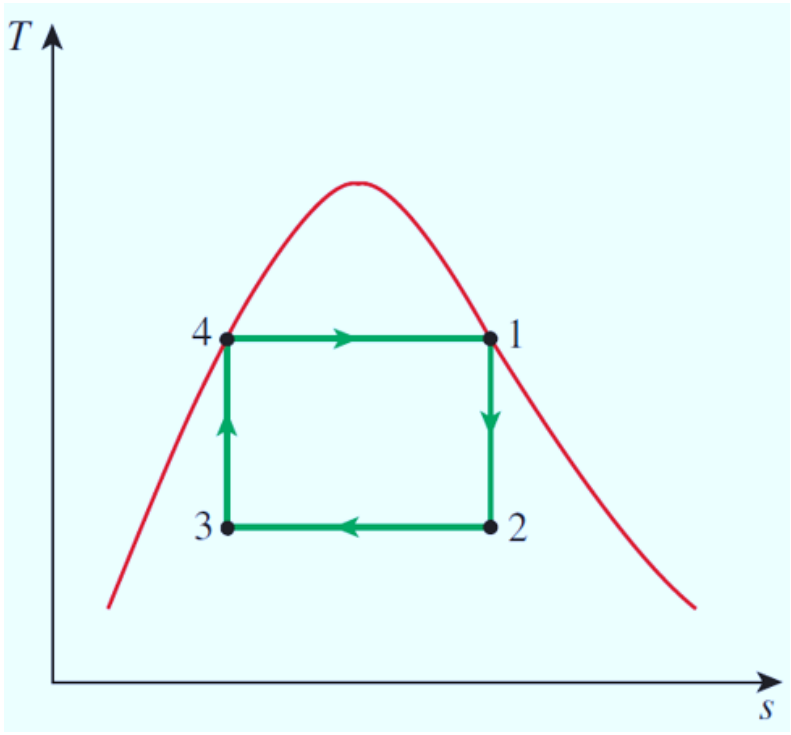
$$\oint \frac{\delta Q}{T} = 0 = \int_1^2 \left(\frac{\delta Q}{T}\right)_C + \int_2^1 \left(\frac{\delta Q}{T}\right)_B$$

$$\int_1^2 \left(\frac{\delta Q}{T}\right)_A = \int_1^2 \left(\frac{\delta Q}{T}\right)_C \Rightarrow dS \equiv \left(\frac{\delta Q}{T}\right)_{\text{rev}}$$

$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_{\text{rev}} = \frac{Q}{T}$$

1. THE CARNOT CYCLE_ Heat Engine with LV substance





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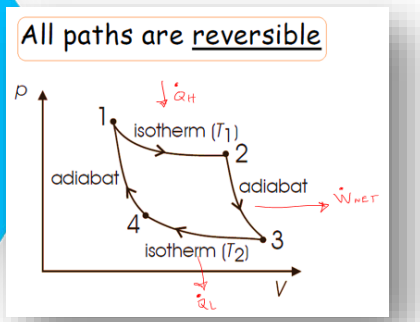
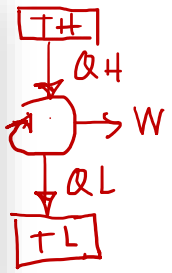
T-s diagram for the Carnot cycle

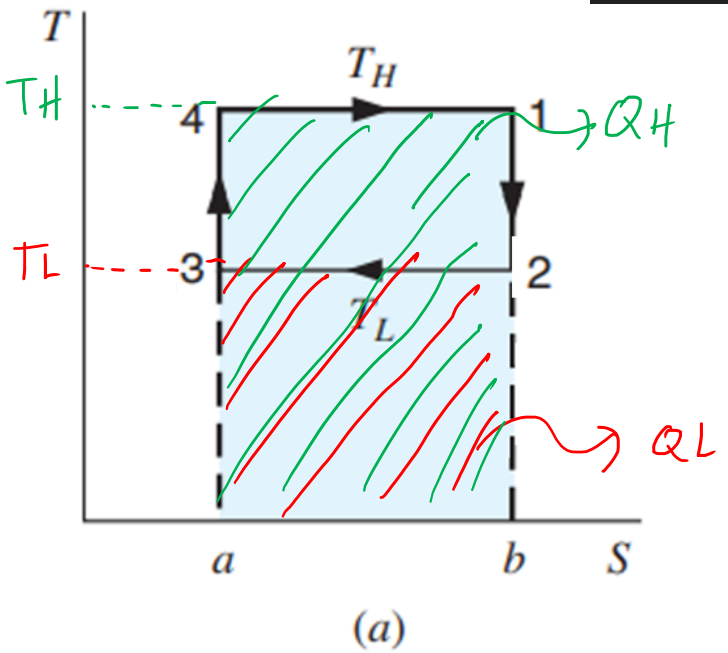




$$dS = \left(\frac{\delta Q}{T}\right)_{\text{rev}}$$

$$S_1 - S_4 = \frac{1}{T_H}\int_4^1 \delta Q = \frac{Q_{14}}{T_H}$$

$$S_3 - S_2 = \int_2^3 \left(\frac{\delta Q}{T}\right)_{\text{rev}} = \frac{Q_{32}}{T_L}$$



$$\eta_{th} = \frac{|W_{net}|}{Q_H} = \frac{\text{area } 4\text{-}1\text{-}2\text{-}3\text{-}4}{\text{area } 4\text{-}1\text{-}b\text{-}a\text{-}4}$$

$|Q_H| - |Q_L|$

THE CARNOT CYCLE AS **HEAT ENGINE….MASS CONTROL**

Mathematical statement:

$$\oint \frac{\delta Q_{rev}}{T} = 0 \quad and$$

$$\frac{dE}{dt} = \dot{Q}_{NETO} - \dot{W}_{NETO}$$

$\hookrightarrow Q_H + Q_L$

$$|\dot{Q}_{NETO}| = |\dot{Q}_H| - |\dot{Q}_L| = |\dot{W}_{NETO}|$$

Reversible

Para un proceso reversible $|Q_L|$ es mínimo $\Rightarrow |\dot{Q}_{NETO}|_{max}$

$\hookrightarrow \dot{Q}_{rev}$

The Inequality of Clausius

$$\oint \frac{\delta Q}{T} \leq 0$$

$= 0$ no irreversibilities present within the system (Reversible)

< 0 irreversibilities present within the system

> 0 impossible

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↳ Este ppio de ↑ de entropía Lo demostraremos despues

POSTULADO: La entropía del universo siempre aumenta

↳ sistema + alrededores

↳ por eso hablamos de frontera de ahora en adelante

Clausius Inequality…Cycles….$T_{boundary}$ …. Control Mass

Searching by application in processes in addition to cycles!!

$$\oint \left(\frac{\delta Q}{T}\right)_b \leq 0$$

$= 0$ no irreversibilities present within the system (reversible)

< 0 irreversibilities present within the system

> 0 impossible

The **Clausius inequality** can be expressed equivalently as

$$\oint \left(\frac{\delta Q}{T}\right)_b = -\sigma_{cycle}$$

In summary, the nature of a cycle executed by a system is indicated by the value for σ_{cycle} as follows:

$\sigma_{cycle} = 0$ no irreversibilities present within the system (reversible)

$\sigma_{cycle} > 0$ irreversibilities present within the system

$\sigma_{cycle} < 0$ impossible

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Clausius Inequality…Cycles….$T_{boundary}$ …. Control Mass

Searching by application in processes in addition to cycles!!

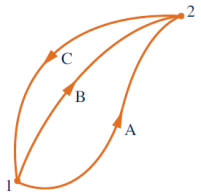
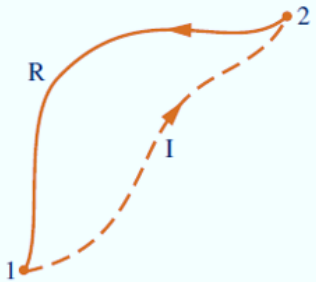


Fig. 6.1 Two internally reversible cycles.

$$S_2 - S_1 = \left(\int_1^2 \frac{\delta Q}{T} \right)_{\substack{\text{int} \\ \text{rev}}}$$

$$\oint \left(\frac{\delta Q}{T} \right)_b = -\sigma_{\text{cycle}} \quad (5.13)$$

PARA EL CICLO



$$\int_1^2 \left(\frac{\delta Q}{T} \right)_b + \int_2^1 \left(\frac{\delta Q}{T} \right)_{\substack{\text{Int} \\ \text{rev}}} < 0$$

$$\int_1^2 \left(\frac{\delta Q}{T} \right)_b + \int_2^1 \left(\frac{\delta Q}{T} \right)_{\substack{\text{Int} \\ \text{rev}}} = -\sigma$$

$$\int_1^2 \left(\frac{\delta Q}{T} \right)_b + (S_1 - S_2) = -\sigma$$

$$\int_1^2 \left(\frac{\delta Q}{T} \right)_b + \sigma = (S_2 - S_1)$$

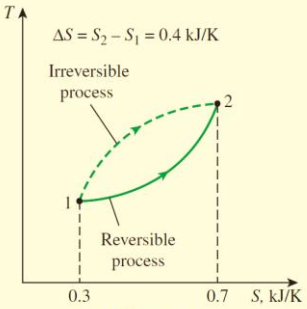


FIGURE 7–3

The entropy change between two specified states is the same whether the process is reversible or irreversible.

But **σ** depends of each irreversible path, therefore this is not a property.

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Closed system entropy balance

In symbols, the closed system entropy balance takes the form:

$$dS = \left(\frac{\delta Q}{T}\right)_b + \delta\sigma$$

[*change* in the amount of entropy contained within the system during some time interval] = [net amount of entropy *transferred in* across the system boundary during the time interval] + [amount of *entropy produced* within the system during the time interval]

$$\underbrace{S_2 - S_1}_{\text{entropy change}} = \underbrace{\int_1^2 \left(\frac{\delta Q}{T}\right)_b}_{\text{entropy transfer}} + \underbrace{\sigma}_{\text{entropy productio}}$$

Closed system entropy balance

$$\underbrace{\int_1^2 \left(\frac{\delta Q}{T}\right)_b}_{\text{entropy transfer}}$$

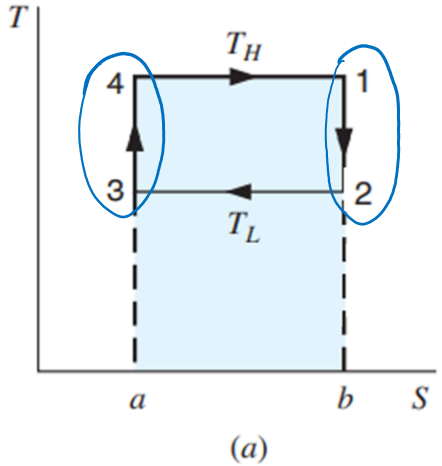
*This can be interpreted to mean that an **entropy transfer** *accompanies* heat transfer (The direction of the entropy transfer is the same as that of the heat transfer)

$$\underbrace{\sigma}_{\text{entropy production}}$$

The term is positive when internal irreversibilities are present during the process and vanishes when no internal irreversibilities are present. This can be described by saying that **entropy is produced** (or *generated*) within the system by the action of irreversibilities.

- In an *adiabatic* internally reversible process, entropy remains constant. A constant-entropy process is called an **isentropic process**.

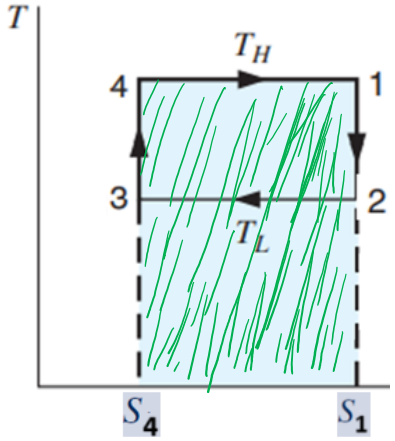
$$S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma \Rightarrow S_2 = S_1$$



(a)

- Another special case is the reversible-isothermal process, we will see some examples **(Q = TΔS)**

$$S_1 - S_4 = \int_4^1 \left(\frac{\delta Q}{T}\right)_b + \sigma \Rightarrow S_1 - S_4 = \frac{1}{T_H}\int_4^1 \delta Q \Rightarrow S_1 - S_4 = \frac{Q_{14}}{T_H}$$



Closed system entropy balance

$$\underbrace{S_2 - S_1}_{\text{entropy change}} = \underbrace{\int_1^2 \left(\frac{\delta Q}{T}\right)_b}_{\text{entropy transfer}} + \underbrace{\sigma}_{\text{entropy production}}$$

The second law requires that entropy *production* be positive, or zero, in value:

$$\sigma: \begin{cases} > 0 & \text{irreversibilities present within the system} \\ = 0 & \text{no irreversibilities present within the system} \\ < 0 & \text{Impossible. This cannot happen.} \end{cases}$$

The value of the entropy production cannot be negative. In contrast, the *change* in entropy of the system may be positive, negative, or zero:

$$S_2 - S_1: \begin{cases} > 0 \\ = 0 \\ < 0 \end{cases}$$

Like other properties, entropy change for a process between two specified states can be determined without knowledge of the details of the process.

Liquids – Solids

- Entropy Change of an Incompressible Substance
- Water/Refrigerants – use tables like u and h
- Entropy Change of an Ideal Gas

Hoy

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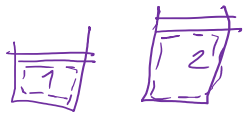
$$\Delta V = Q_{12} - W_{12}$$

masa de control: $\int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma = S_2 - S_1$

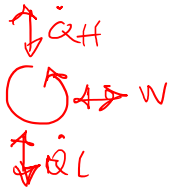


→ un proceso no un ciclo

$$\int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma = (S_2 - S_1)$$

↳ ciclo (visto como masa de control)

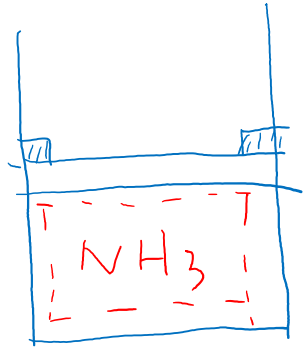
$$\oint_{ciclo} \left(\frac{\delta Q}{T}\right)_b + \sigma_{ciclo} = S_2 - S_1 \to 0$$

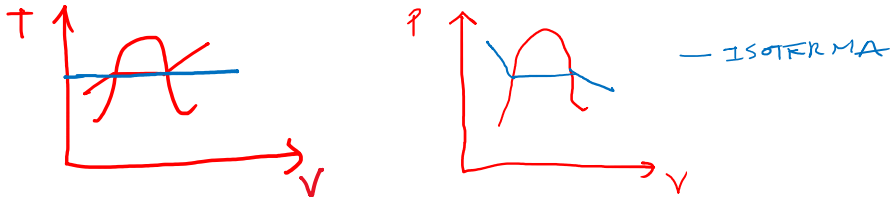


Exercise 1: Five kilograms of ammonia in a piston cylinder at 30°C and 1000 kPa expands in a reversible isothermal process to 200 kPa. Find the work [**kJ**] and heat transfer [**kJ**] for this process. Also make the P[bar]-v[m3/kg] diagram (W) and the T[°C]-s[kJ/kg.K] diagram (Q)

Solución:

Definimos el sistema:





La masa contenida en el cilindro – émbolo permanece constante

Balance de primera ley:

$$m(u_2 - u_1) = Q_{12} - W_{12}$$

Segunda ley para procesos reversibles:

$$\int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma^{0} = (S_2 - S_1)$$

$\frac{Q_{12}}{T} = m(s_2 - s_1)$

$\int \frac{\delta Q}{T} + 0 = s_2 - s_1$

$0 + s_1 = s_2$

Buscando en tablas, determinamos los estados y las propiedades necesarias:

Estado 1(30°C and 1000 kPa): Vapor sobrecalentado
u_1= 1346.82 kJ/kg
s_1= 5.0816 kJ/kg.K

Estado 2 (30°C and 200 kPa): : Vapor sobrecalentado
u_2= 1386.56 kJ/kg
s_2= 6.0014 kJ/kg.K

	p = 9.0 bar = 0.90 MPa (T_{sat} = 21.52°C)				p = 10.0 bar = 1.00 MPa (T_{sat} = 24.89°C)			
	v	u	h	s	v	u	h	s
Sat.	0.14239	1332.82	1460.97	5.0675	0.12852	1334.66	1463.18	5.0294
30	0.14872	1352.36	1486.20	5.1520	0.13206	1346.82	1478.88	5.0816
40	0.15582	1374.21	1514.45	5.2436	0.13868	1369.52	1508.20	5.1768
50	0.16263	1395.11	1541.47	5.3286	0.14499	1391.07	1536.06	5.2644
60	0.16922	1415.32	1567.61	5.4083	0.15106	1411.79	1562.86	5.3460
80	0.18191	1454.39	1618.11	5.5555	0.16270	1451.60	1614.31	5.4960
100	0.19416	1492.50	1667.24	5.6908	0.17389	1490.20	1664.10	5.6332
120	0.20612	1530.30	1715.81	5.8176	0.18478	1528.35	1713.13	5.7612
140	0.21788	1568.20	1764.29	5.9379	0.19545	1566.51	1761.96	5.8823
160	0.22948	1606.46	1813.00	6.0530	0.20598	1604.97	1810.94	5.9981
180	0.24097	1645.24	1862.12	6.1639	0.21638	1643.91	1860.29	6.1095
200	0.25237	1684.64	1911.77	6.2711	0.22670	1683.44	1910.14	6.2171

1000 kPa

$v_1 = 0.13206 \ \frac{m^3}{kg}$

	p = 1.5 bar = 0.15 MPa (T_{sat} = −25.22°C)				p = 2.0 bar = 0.20 MPa (T_{sat} = −18.86°C)			
Sat.	0.7787	1293.80	1410.61	5.6973	0.59460	1300.39	1419.31	5.5969
−25	0.7795	1294.20	1411.13	5.6994				
−20	0.7978	1303.00	1422.67	5.7454				
−15	0.8158	1311.75	1434.12	5.7902	0.60542	1307.43	1428.51	5.6328
−10	0.8336	1320.44	1445.49	5.8338	0.61926	1316.46	1440.31	5.6781
−5	0.8514	1329.08	1456.79	5.8764	0.63294	1325.41	1452.00	5.7221
0	0.8689	1337.68	1468.02	5.9179	0.64648	1334.29	1463.59	5.7649
5	0.8864	1346.25	1479.20	5.9585	0.65989	1343.11	1475.09	5.8066
10	0.9037	1354.78	1490.34	5.9981	0.67320	1351.87	1486.51	5.8473
15	0.9210	1363.29	1501.44	6.0370	0.68640	1360.59	1497.87	5.8871
20	0.9382	1371.79	1512.51	6.0751	0.69952	1369.28	1509.18	5.9260
25	0.9553	1380.28	1523.56	6.1125	0.71256	1377.93	1520.44	5.9641
30	0.9723	1388.76	1534.60	6.1492	0.72553	1386.56	1531.67	6.0014

200 kPa

$v_2 = 0.72553 \ \frac{m^3}{kg}$

Determinamos la transferencia de calor en el proceso:

$Q_{12} = Tm\,(s_2 - s_1)$

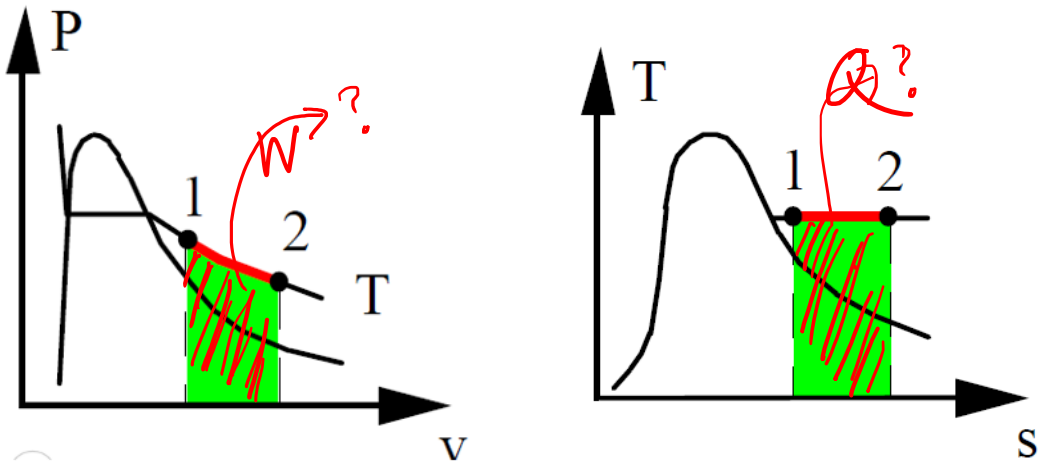
$$Q_{12} = 5\text{kg}(303.15\ \text{K})(6.0014 - 5.0816)\ \text{kJ/kg.K} = \mathbf{1394.1869\ kJ}$$

Luego despejamos el trabajo del balance de primera ley para determinarlo:

$$W_{12} = Q_{12} - m(u_2 - u_1) = 1394.1869\ \text{kJ} - 5\text{kg}(1386.56 - 1346.82)\ \text{kJ/kg} = \mathbf{1195.4869\ kJ}$$

GIDEAL

Realizamos los diagramas P-v y T-s para el amoniaco:



Tarea - Completar los gráficos con las propiedades respectivas.

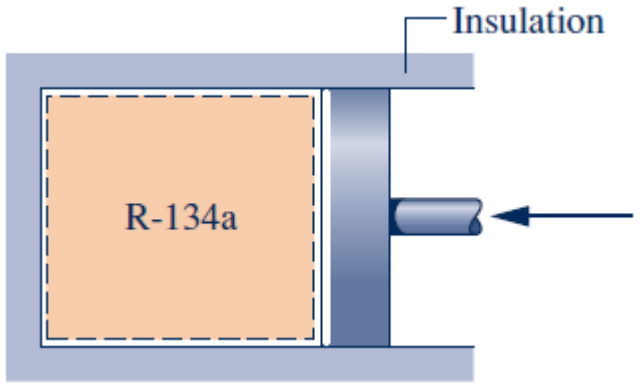
Evaluating Minimum Theoretical Compression Work

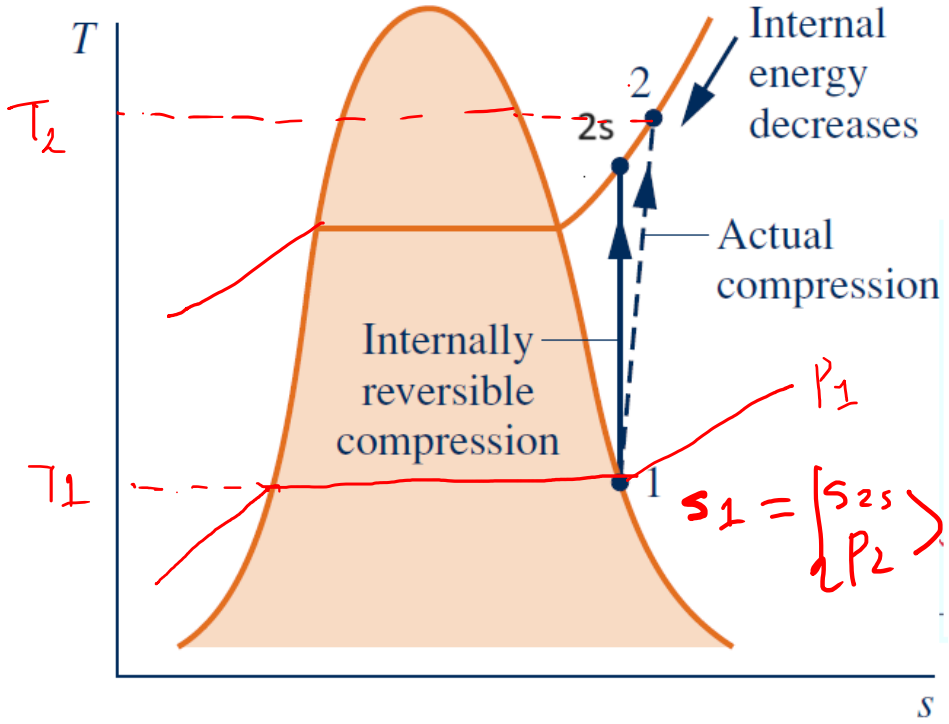
Exercise 2: :

Refrigerant 134a is compressed adiabatically in a piston–cylinder assembly from saturated vapor at $-26°C$ to a final pressure of 800 kPa and $50°C$. a) Determine the actual and the minimum theoretical work input required per unit mass of refrigerant (kJ/kg). In both cases the P_2 is the same. b) The entropy production(kJ/kg.K) for the actual process.

Considerations:

1. The Refrigerant 134a is a closed system.
2. There is no heat transfer with the surroundings.
3. The initial and final states are equilibrium states. There is no change in kinetic or potential energy between these states.





Evaluating Minimum Theoretical Compression Work

Problem Statement:

Refrigerant 134a is compressed adiabatically in a piston–cylinder assembly from saturated vapor at $-26°C$ to a final pressure of 800 kPa and $50°C$. a) Determine the actual and the minimum theoretical work input required per unit mass of refrigerant, in kJ/kg, for both cases the P_2 is the same. b) The entropy production(kJ/kg.K) for the actual process.

→ W_{actual}

a1. **Analysis:** An expression for the work can be obtained from an energy balance. By applying assumptions 2 and 3, we get

$$\Delta U + \Delta KE^{0} + \Delta PE^{0} = Q^{0} - W \Rightarrow m(\Delta u) = -W$$

When written on a unit mass basis, the work *input* is then $\left(-\frac{W}{m}\right) = u_2 - u_1 = 261.62 - 212.43 = 49.19 \ \frac{kJ}{kg}$

↳ ACTUAL WORK

1

Pressure Conversions:
1 bar = 0.1 MPa
$= 10^2$ kPa

Properties of Saturated Refrigerant 134a (Liquid–Vapor): Temperature Table

TABLE A-10

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Temp. °C
−26	1.0199	0.7265	0.1882	16.75	212.43	16.82	214.80	231.62	0.0699	0.9390	−26

2

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
$p = 8.0$ bar $= 0.80$ MPa ($T_{sat} = 31.33°C$)				
Sat.	0.02547	243.78	264.15	0.9066
40	0.02691	252.13	273.66	0.9374
50	0.02846	261.62	284.39	0.9711

b) $m(s_2 - s_1) = \int \frac{\delta Q}{T}^{0} + \sigma \Rightarrow \frac{\sigma}{m} = 0.9711 - 0.9390 = 0.0321 \ \frac{kJ}{kg.k}$

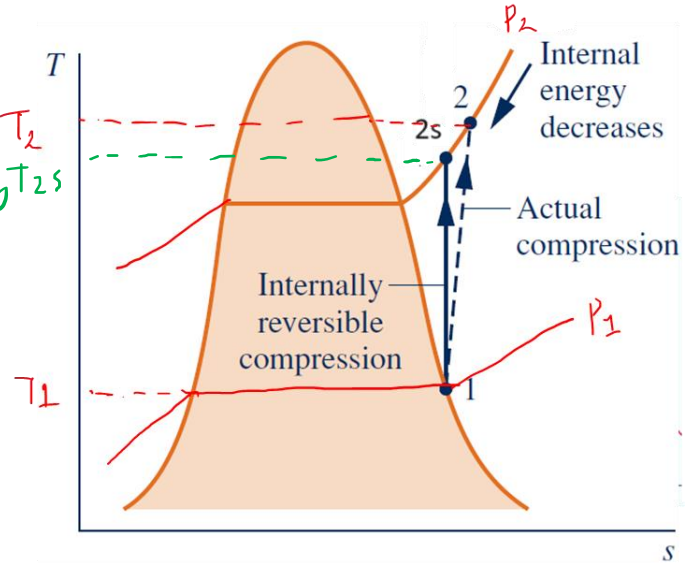
Evaluating Minimum Theoretical Compression Work

Problem Statement:

Refrigerant 134a is compressed adiabatically in a piston–cylinder assembly from saturated vapor at $-26°C$ to a final pressure of 800 kPa and $50°C$. Determine the actual and the minimum theoretical work input required per unit mass of refrigerant, in kJ/kg, for both cases the P_2 is the same.

a2. Ideal case (Ideal) → $s_2 - s_1 = \frac{\sigma}{m} = 0 \Rightarrow$ Estado 2 ideal $\begin{cases} P_2 = 8 \text{ bar} \\ s_{2s} = s_1 = 0.9390 \frac{KJ}{KgK} \end{cases}$

↳ Interpolando $\begin{cases} u_{2s} = 252.5806 \text{ KJ/Kg} \\ T_{2s} = 40.4748 °C \end{cases}$



$$-\frac{W_{ideal}}{m} = u_{2s} - u_1 = 252.5806 - 212.43 = 40.1506 \frac{KJ}{Kg}$$ (minimum)

Pressure Conversions: 1 bar = 0.1 MPa = 10^2 kPa

TABLE A-10 Properties of Saturated Refrigerant 134a (Liquid–Vapor): Temperature Table

Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Specific Volume m³/kg: Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Internal Energy kJ/kg: Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Enthalpy kJ/kg: Evap. h_{fg}	Enthalpy kJ/kg: Sat. Vapor h_g	Entropy kJ/kg · K: Sat. Liquid s_f	Entropy kJ/kg · K: Sat. Vapor s_g	Temp. °C
−26	1.0199	0.7265	0.1882	16.75	212.43	16.82	214.80	231.62	0.0699	0.9390	−26

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
$p = 8.0$ bar = 0.80 MPa ($T_{sat} = 31.33°C$)				
Sat.	0.02547	243.78	264.15	0.9066
40	0.02691	252.13	273.66	0.9374
50	0.02846	261.62	284.39	0.9711

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Exercise 3: A system executes a power cycle while receiving 1000 kJ by heat transfer at a temperature of 500 K and discharging energy by heat transfer at a temperature of 300 K. There are no other heat transfers. Applying Eq. BELOW, determine σ_{cycle} if the thermal efficiency is (a) 100%, (b) 40%, (c) 25%. Identify cases (if any) that are internally reversible or impossible

masa de control: $\int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma = S_2 - S_1$

$$\int_1^2 \left(\frac{\delta Q}{T}\right)_b + \sigma = (S_2 - S_1)$$

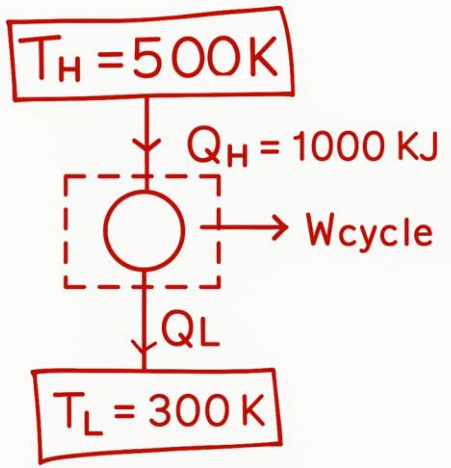
↳ ciclo (visto como masa de control)

$\oint_{ciclo} \left(\frac{\delta Q}{T}\right)_b + \sigma_{ciclo} = S_2 - S_1 = 0$

↳ 5.13

$\eta = 1 - \frac{|Q_L|}{|Q_H|}$

SCHEMATIC GIVEN DATA



$\sigma_{cycle} = 0$ no irreversibilities present within the system

$\sigma_{cycle} > 0$ irreversibilities present within the system

$\sigma_{cycle} < 0$ impossible

For a thermal cycle,

$$\eta = 1 - \frac{|Q_L|}{|Q_H|} \implies |Q_L| = (1-\eta)|Q_H|$$

Then, Eq. 5.13 reads:

$$\sigma_{\text{cycle}} = -\int \left(\frac{\delta Q}{T}\right)_{\text{b}} = -\left[\frac{|Q_H|}{T_H} - \frac{|Q_L|}{T_L}\right] = -\left[\frac{|Q_H|}{T_H} - \frac{(1-\eta)|Q_H|}{T_L}\right] = -|Q_H|\left[\frac{1}{T_H} - \frac{(1-\eta)}{T_L}\right] = -1000\,\text{kJ}\left[\frac{1}{500\,\text{K}} - \frac{(1-\eta)}{300\,\text{K}}\right]$$

(a) $\eta = 1$ (100%)

$$\sigma_{\text{cycle}} = -1000\,\text{kJ}\left[\frac{1}{500\,\text{K}} - 0\right] = -2\,\text{kJ/K}$$

Since σ_{cycle} cannot be negative, this case is impossible.

IDEAL EFFICIENCY (CARNOT) ??

1. The maximum thermal efficiency any such cycle can have is:

$$\eta_{MAX} = \left[1 - \frac{T_L}{T_H}\right] = \left[1 - \frac{300\,\text{K}}{500\,\text{K}}\right] = 0.4\,(40\%)$$

(b) $\eta = 0.4$ (40%)

$$\sigma_{cycle} = -1000\,\text{kJ}\left[\frac{1}{500\,\text{K}} - \frac{(1-0.4)}{300\,\text{K}}\right] = 0$$

Since $\sigma_{cycle} = 0$, this case corresponds to internally reversible operation.

(c) $\eta = 0.25$ (25%)

$$\sigma_{\text{cycle}} = -1000\,\text{kJ}\left[\frac{1}{500\,\text{K}} - \frac{(1-0.25)}{300\,\text{K}}\right] = 0.5\,\text{kJ/K}$$

Since $\sigma_{\text{cycle}} > 0$, this case corresponds to the presence of internal irreversibilities.

Thanks!

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