Thermodynamic_2026_1

Second Law_S10_1

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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

S8 A
S16 F

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

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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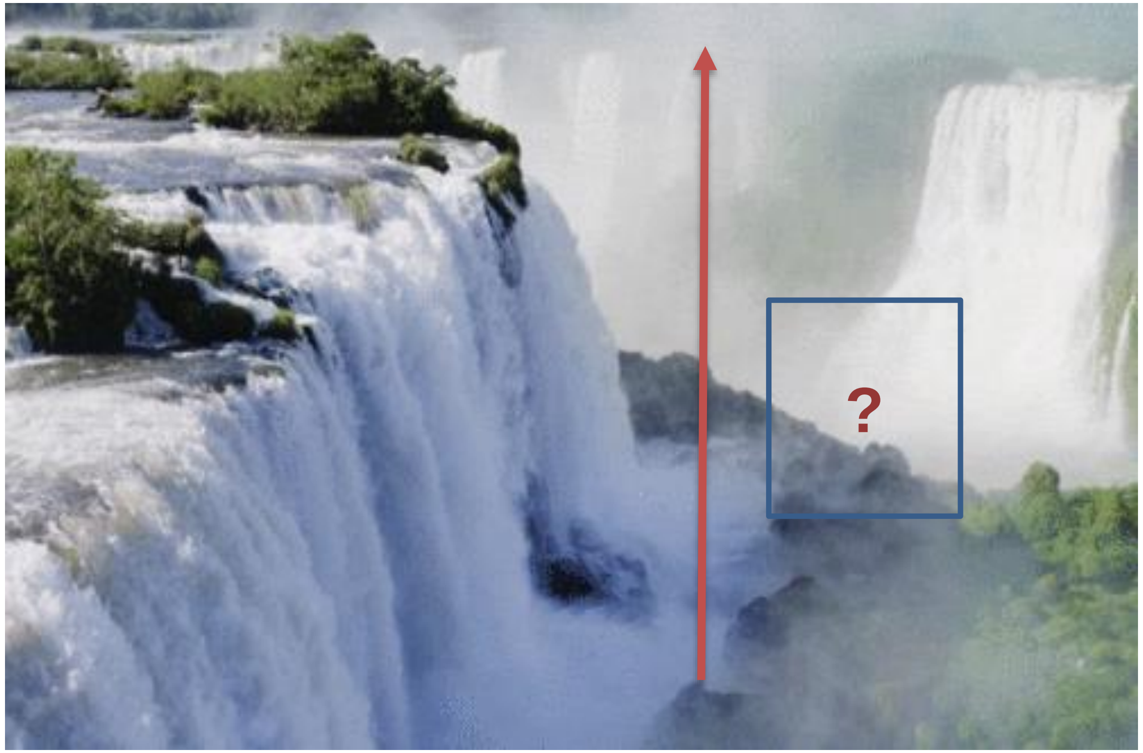
OBJECTIVE

Session 20: Apply the second law of thermodynamics to cycles through the calculation of efficiencies and performance coefficients. Apply the ideal cycle concept using the Carnot cycle as a reference



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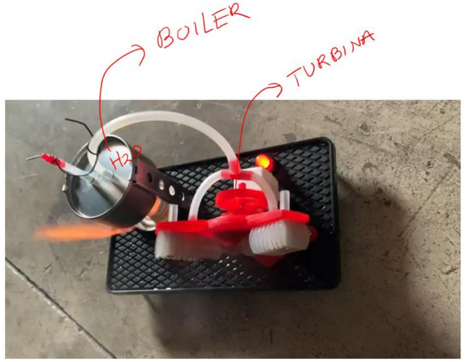

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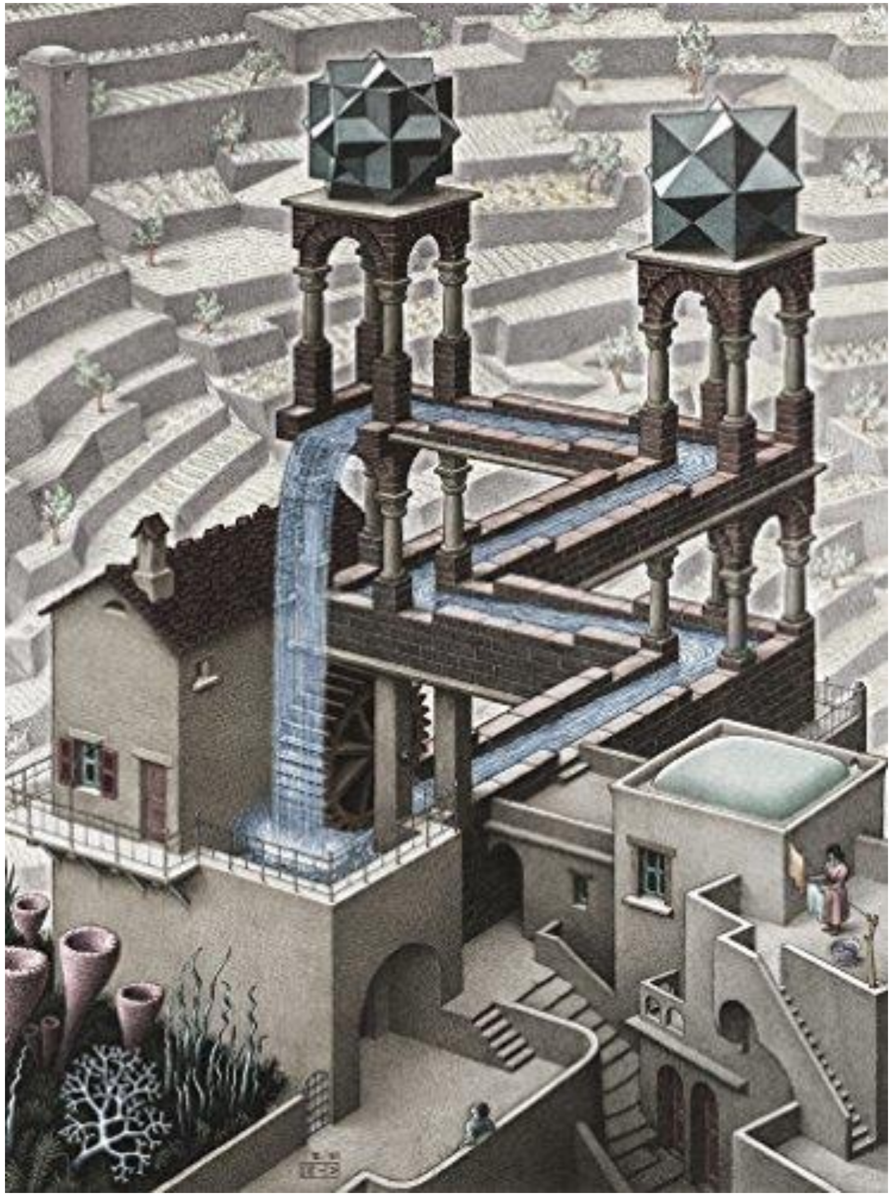
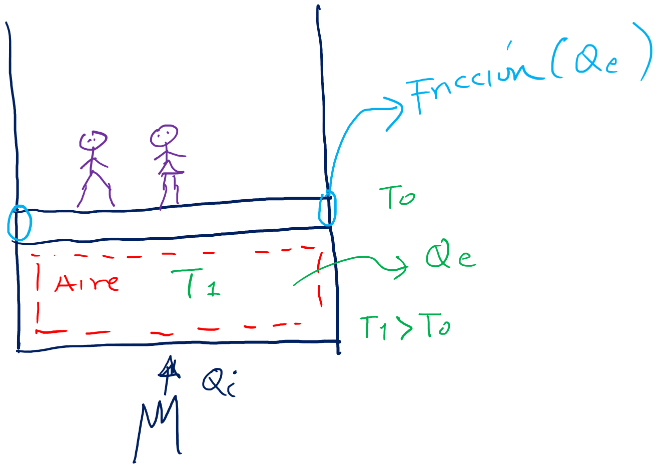
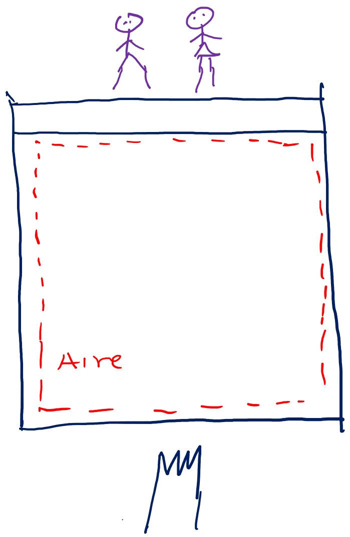
M.C. Escher







$$\Delta U = Q_{NET} - W_{NET}$$

$$W_{NET} = Q_{NET} - \Delta U$$

$$W_{NET} = |Q_i| - |Q_e| - \Delta U$$

Si $Q_e \uparrow$ (por fricción o por transf. de calor [ΔT]) $\Rightarrow W_{NET} \downarrow$

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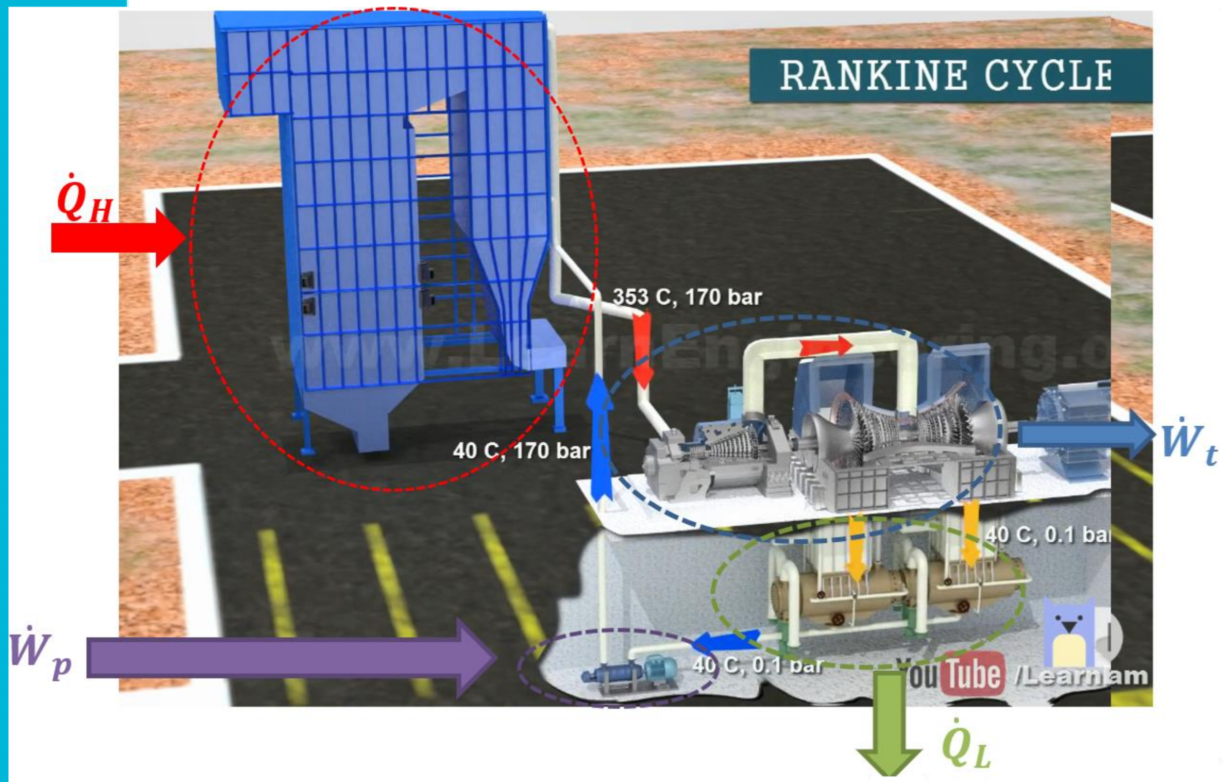
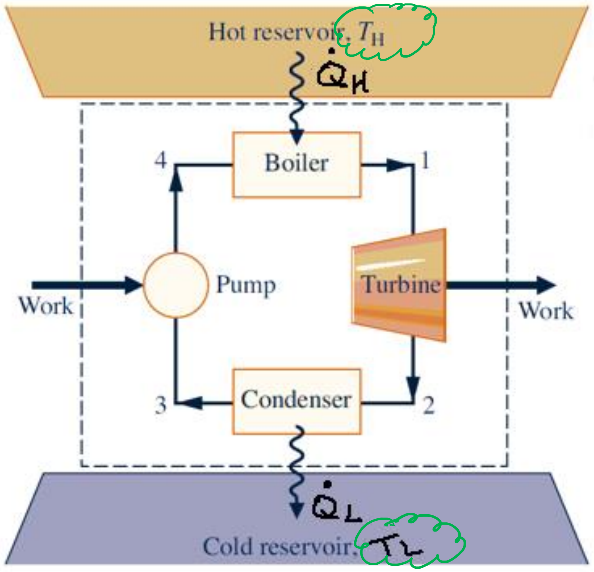
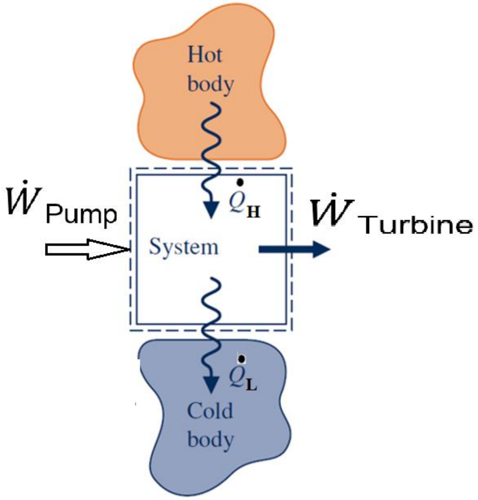




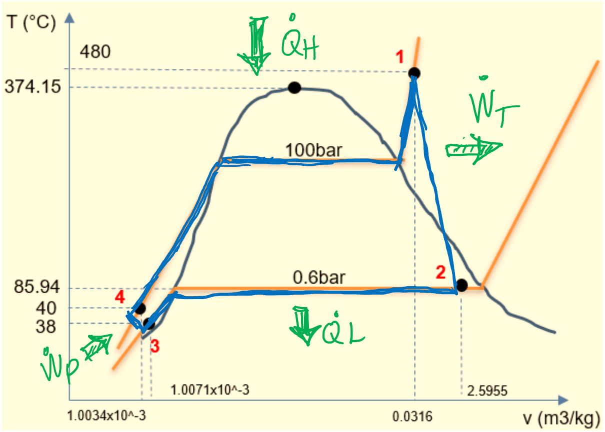


E.E.

$$\frac{\cancel{d}E}{dt} = \dot{Q} - \dot{W}$$

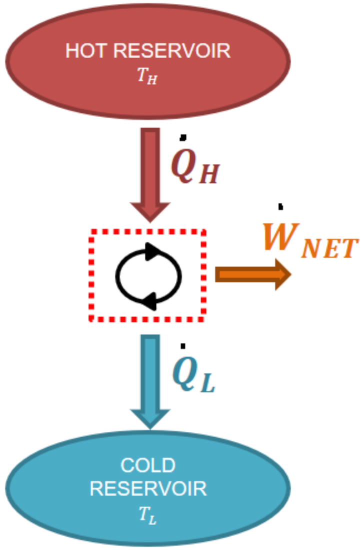
$$\dot{Q}_{NET} = \dot{Q}_H + \dot{Q}_L = W_{NET}$$

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



$$\eta = \frac{\dot{W}_{NET}}{|\dot{Q}_H|} = \frac{|\dot{Q}_H| - |\dot{Q}_L|}{|\dot{Q}_H|} = 1 - \left|\frac{\dot{Q}_L}{\dot{Q}_H}\right|$$

CONCEPTS : 2nd LAW __ (K-P) statement



Efficiency of a Heat Engine

$$\eta = \frac{|\dot{W}_{NET}|}{|\dot{Q}_H|} = \frac{\text{Want}}{\text{Cost}}$$

$$\eta = \frac{|\dot{Q}_H| - |\dot{Q}_L|}{|\dot{Q}_H|} = 1 - \left|\frac{\dot{Q}_L}{\dot{Q}_H}\right|$$

K-P: It is impossible for any system to operate in a cycle that takes heat from a hot reservoir and converts it to work in the surroundings without, at the same time, transferring some heat to a colder reservoir. In other words is impossible to have $\eta = 1$ (since Q_L cannot be zero!).

NOTE: The initial devices satisfy the 1st law if $W_{NET} = Q_H$.
However, They violate the 2nd law!

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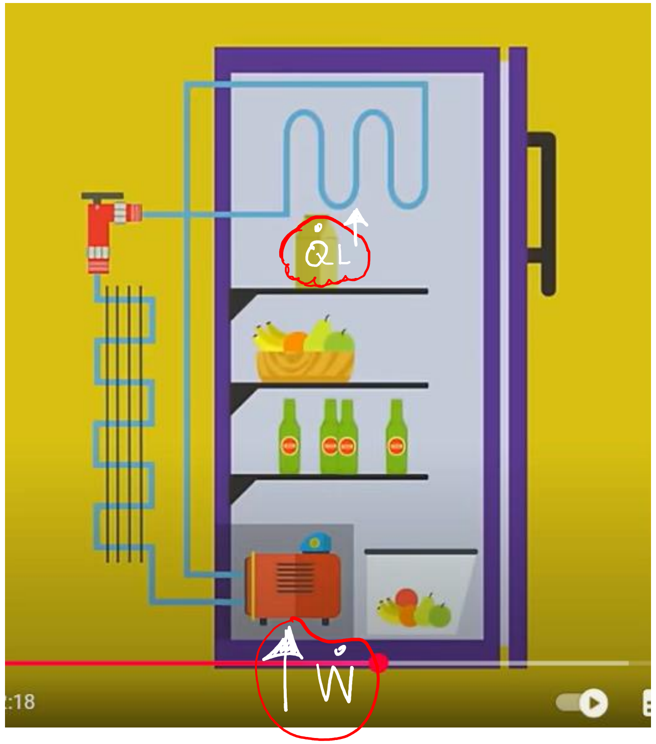
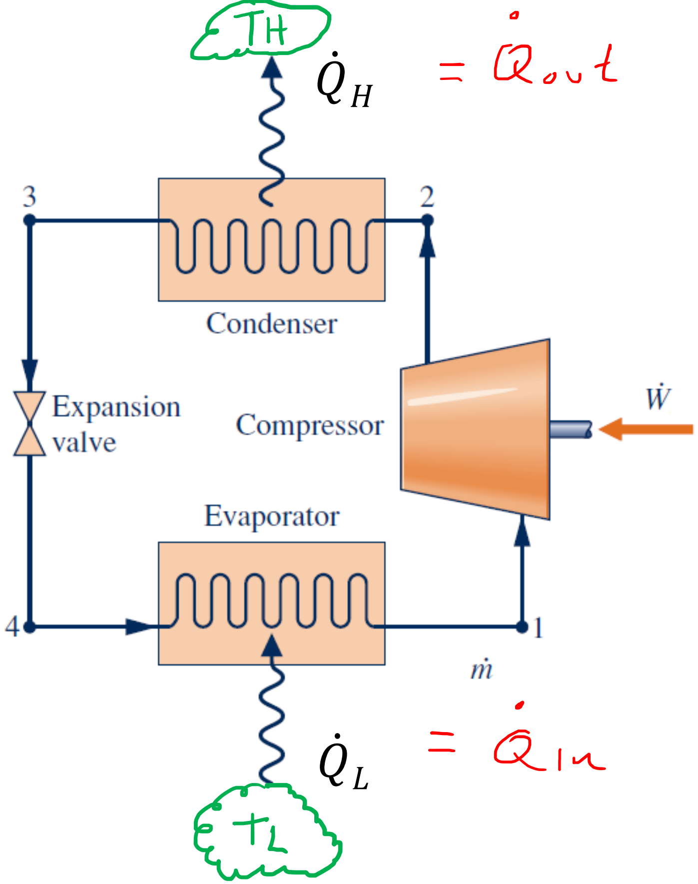
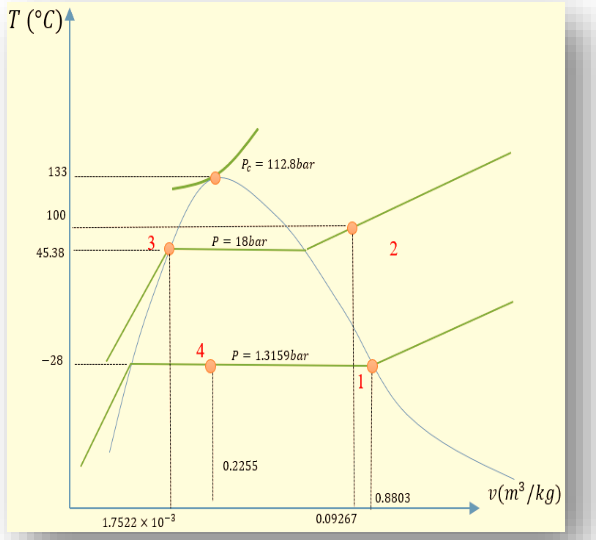
Refrigeration cycle







$$\dot{W} = \dot{Q} = \dot{Q}_H + \dot{Q}_L$$

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

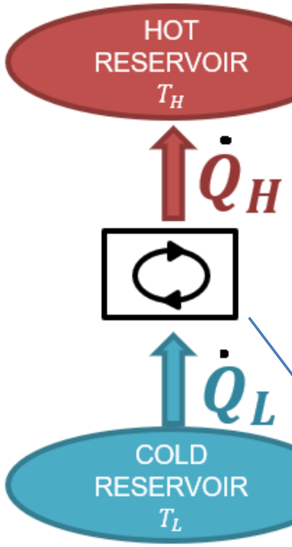
E.E.

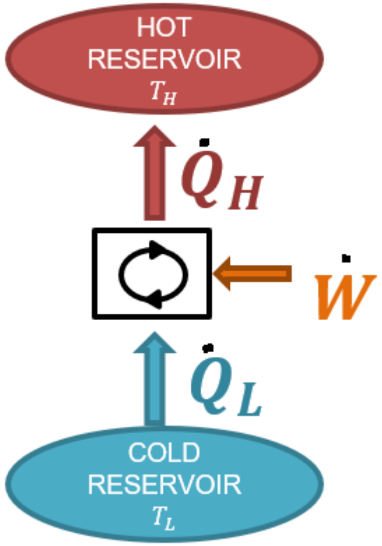
$$\cancel{\frac{dE}{dt}} = \dot{Q} - \dot{W}$$

$$COP_R = \beta_R = \frac{|\dot{Q}_L|}{|\dot{W}|} = \frac{|\dot{Q}_L|}{|\dot{Q}_H| - |\dot{Q}_L|}$$

$$COP_{HP} = \beta_{HP} = \frac{|\dot{Q}_H|}{|\dot{W}|} = \frac{|\dot{Q}_H|}{|\dot{Q}_H| - |\dot{Q}_L|}$$

CONCEPTS : 2nd LAW _Clausius statement (C)





$$COP = \frac{Want}{Costs}$$

$$COP = \beta_R = \frac{|\dot{Q}_L|}{|\dot{W}|} = \frac{|\dot{Q}_L|}{|\dot{Q}_H| - |\dot{Q}_L|}$$

If $\dot{W} = 0,\ COP = \infty$

Clausius: It is impossible for any system to operate in a cycle that takes heat from a cold reservoir and transfers it to a hot reservoir without at the same time converting some work into heat. In other words, a refrigerator does not work spontaneously.

Alternative Clausius statement: All spontaneous processes are **irreversible**

These device satisfy the 1st law : $Q_H = Q_L$, however they violate the 2nd law!!

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

REVERSIBLE PROCESS

A process that can be reversed, returning both the system and the surroundings to their original states

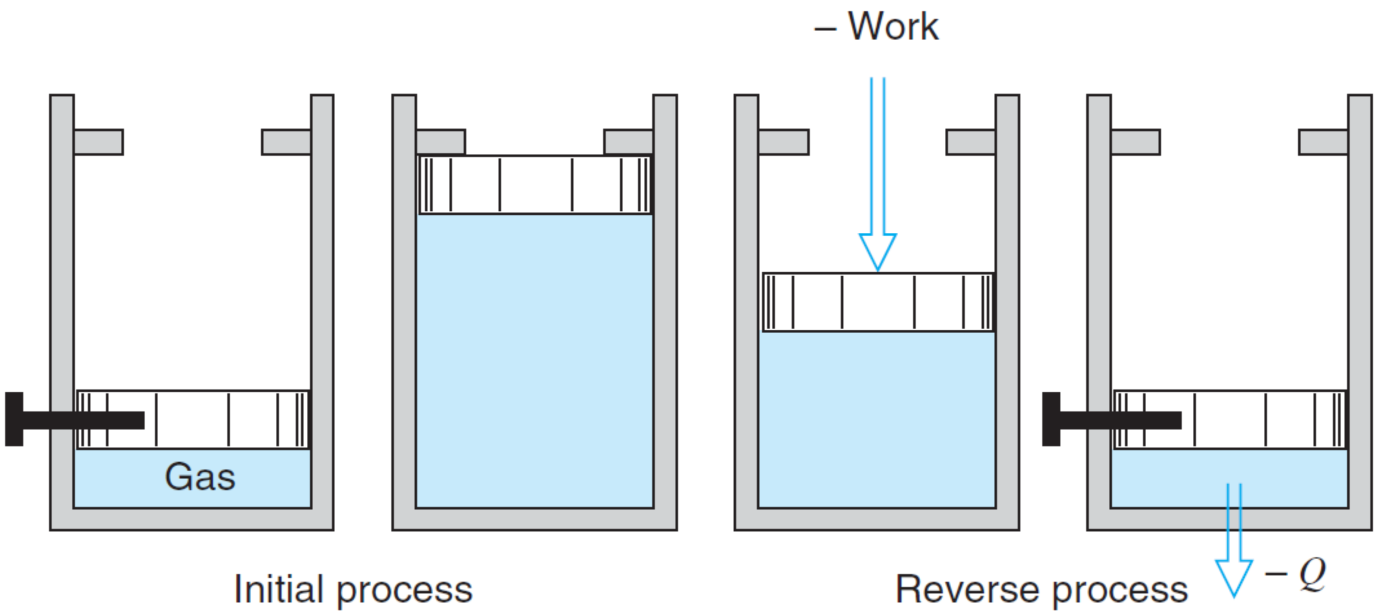
Why don't we have reversible process?

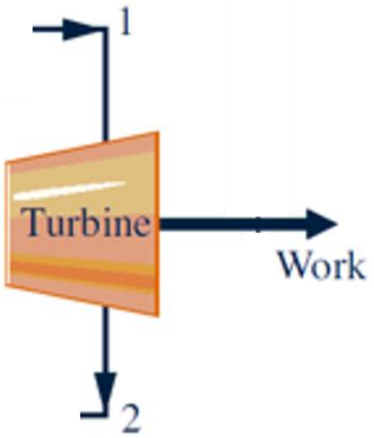
ALL REAL PROCESSES ARE **IRREVERSIBLE**

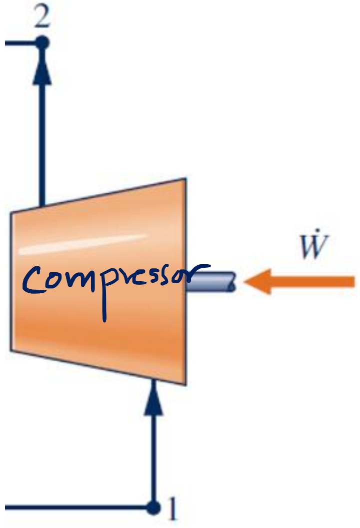
Some reasons: Friction, unrestrained expansion, heat transfer through a finite temperature difference, finite-time process (this means that the process is not quasistatic).

Why don't we have reversible process?

Finite-time process



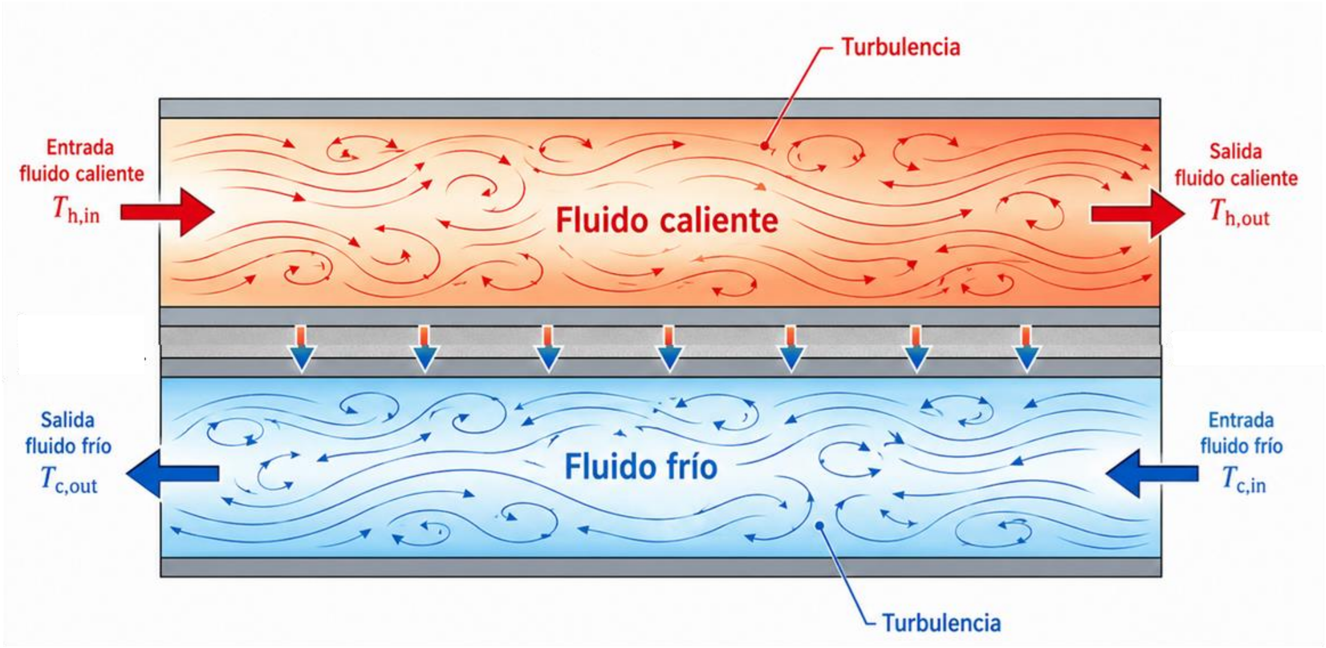




FACTORS THAT RENDER PROCESSES IRREVERSIBLE

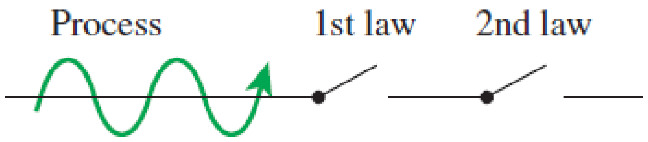
Friction

Irreversibility due to finite temperature difference



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, **<u>the second law of thermodynamics.</u>**



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

Aspects of the Second Law

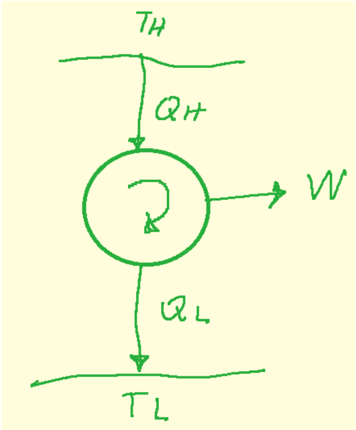
2. Predicting the direction of processes *[possible or not…]*.

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

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

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

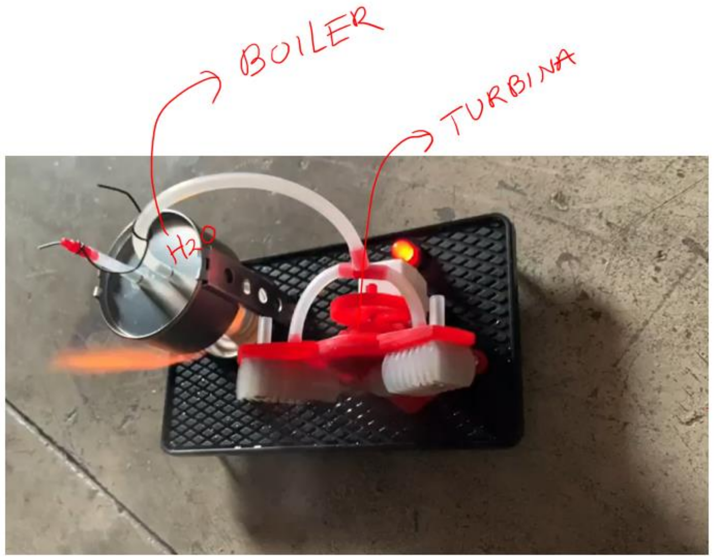


$h(24°C, 1 bar) \approx 100 \frac{kJ}{kg}$ (L.C ≈ L.S)

$h(240°C, 1 bar) \approx 3000 \frac{kJ}{kg}$ (V.S.C)

$100 \frac{kJ}{kg} * \boxed{30 \, kg} = 3000 \, kJ$

$3000 \frac{kJ}{kg} * \boxed{1 \, kg} = 3000 \, kJ$



For now we have the postulates as an approximation to the second law, let's look for ways that allow us to apply it in a more quantitative way....

CARNOT CYCLE

Why do we need ideal cycles?

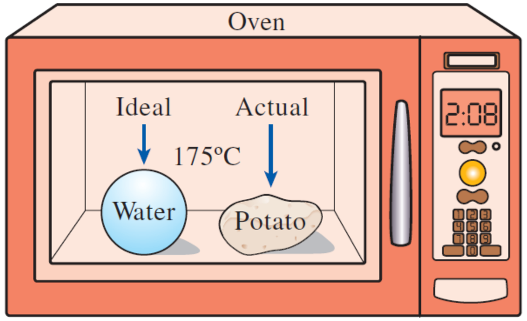


FIGURE Modeling is a powerful engineering tool that provides great insight and simplicity at the expense of some loss in accuracy.

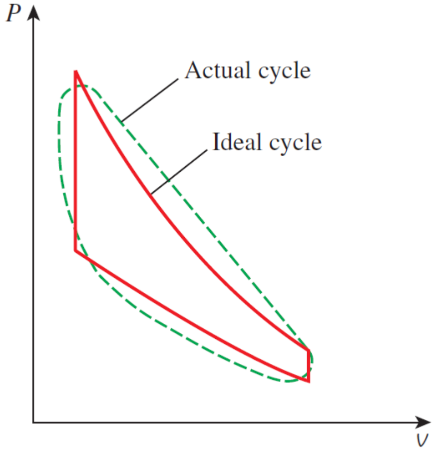


FIGURE The analysis of many complex processes can be reduced to a manageable level by utilizing some idealizations.

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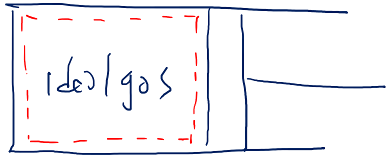
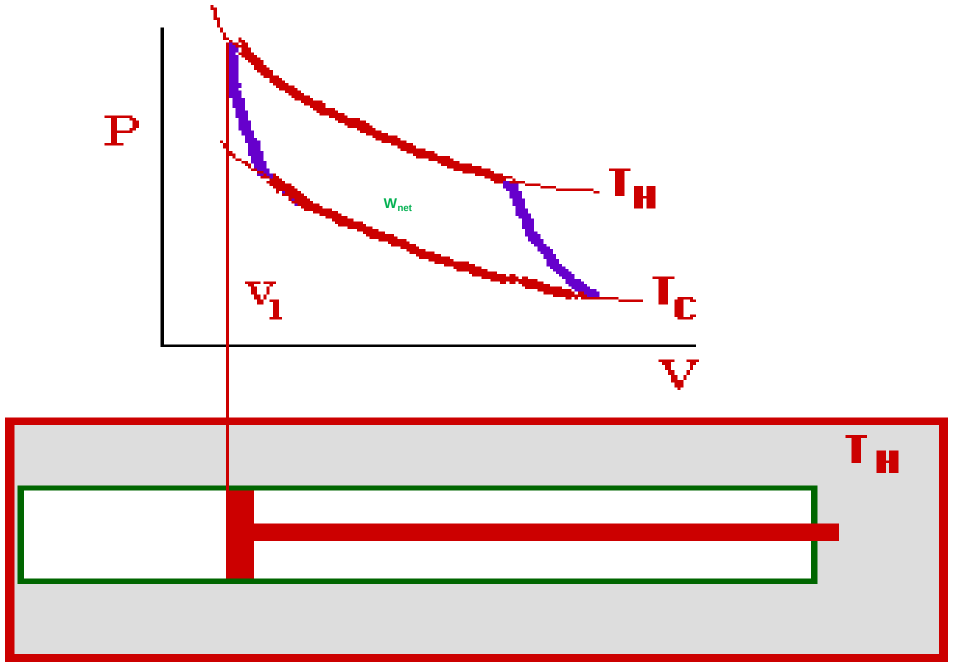
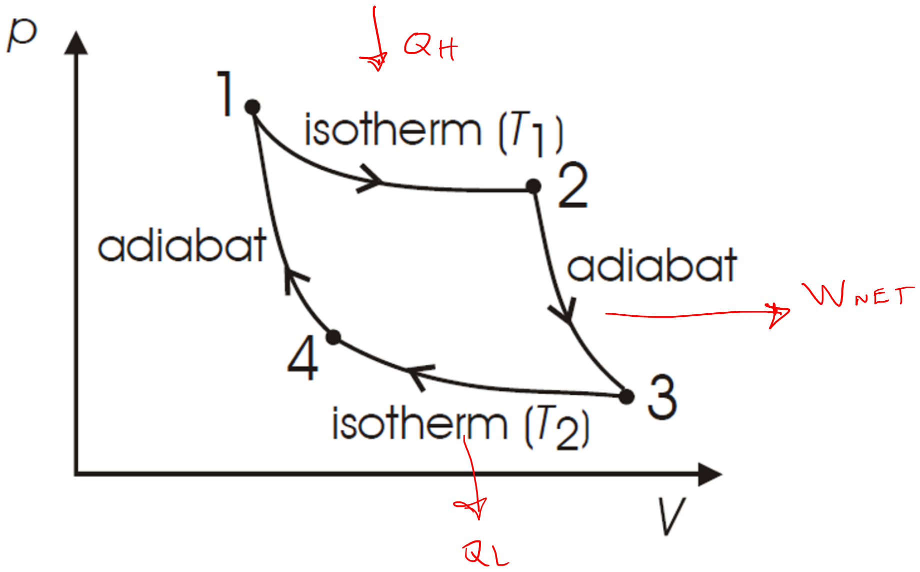
CARNOT_Ideal gas (W_{rev})





$T_C = T_L$

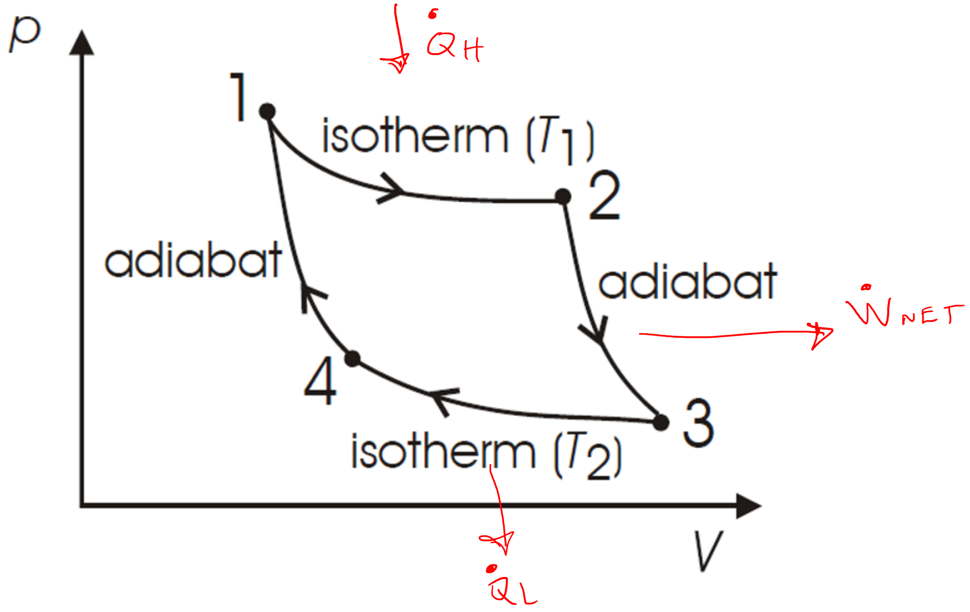
All paths are reversible



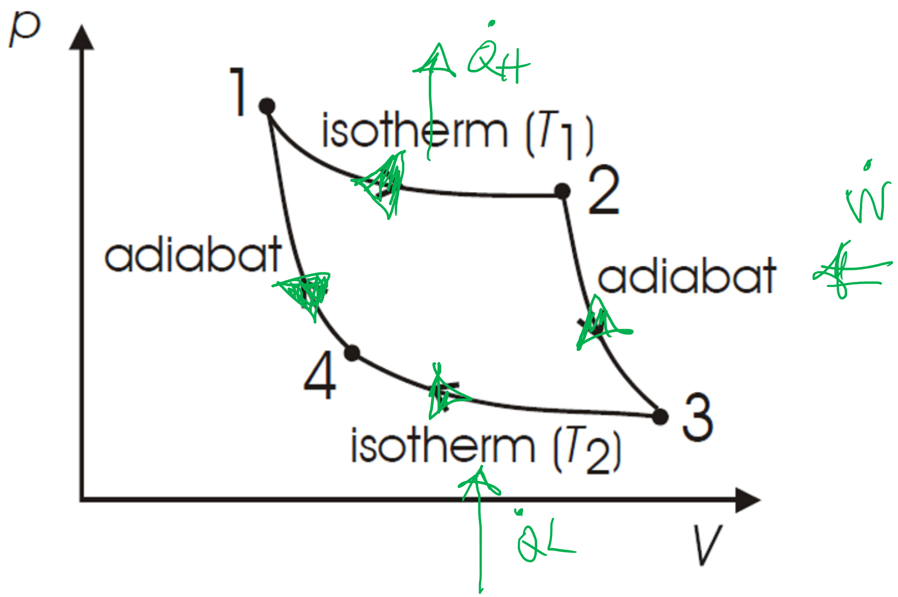
Power cycle?

CARNOT_Ideal gas (W_{rev})

All paths are reversible



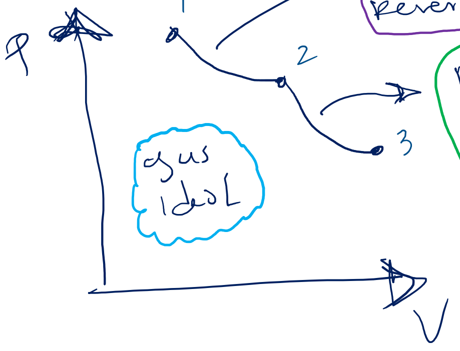
All paths are reversible



Power or Refrigeration cycle?

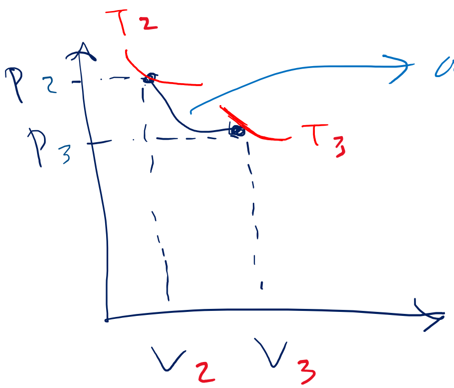
$P_1V_1 = P_2V_2$, $T_1 = T_2$

Isotermico reversible $PV = ct$ $= nRT$



$PV^{\gamma} = ct$

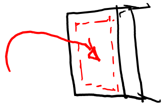
↳ adiabatico reversible



adiabatico reversible

$$P_2V_2^{\gamma} = P_3V_3^{\gamma}, \quad \gamma = \frac{C_p}{C_v}, \quad \frac{T_3}{T_2} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$$

Reversible Adiabatic Expansion (or compression) of an Ideal Gas



1 mole gas (p1, V1, T1) = 1 mole gas (p2, V2,T2)

Demostrate $\left(\frac{T_2}{T_1}\right)=\left(\frac{V_1}{V_2}\right)^{\overset{\gamma}{\Uparrow}\boxed{\frac{\bar{C}_p}{\bar{C}_V}}-1}$ $\boxed{p_1V_1^{\gamma} = p_2V_2^{\gamma}}$ = constant

Considerations:

adiabatic $\Rightarrow$ $\delta Q = 0$

Ideal gas $\Rightarrow$ $dU = \bar{C}_v dT$

1st Law $\therefore$ $dU = \cancel{\delta Q} - \delta W$

$dU = -p\,dV$ [KJ]

$\bar{C}_v dT = -p\,dV$ along path

$$\underset{p=\frac{\bar{R}T}{V}}{\Rightarrow} \quad \bar{C}_V \frac{dT}{T} = -\bar{R}\frac{dV}{V}$$

$$\bar{C}_V \int_{T_1}^{T_2} \frac{dT}{T} = -\bar{R}\int_{V_1}^{V_2} \frac{dV}{V}$$

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\bar{R}/\bar{C}_V} \xrightarrow{\bar{C}_p-\bar{C}_V=\bar{R}\text{ for i.g.}} \left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\frac{\bar{C}_p}{\bar{C}_V}-1}$$

Define $\gamma \equiv \frac{\bar{C}_p}{\bar{C}_V}$ $\Rightarrow$ $\boxed{\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma-1}}$

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Reversible Adiabatic Expansion (or compression) of an Ideal Gas

1 mole gas (p1, V1, T1) = **1 mole gas** (p2, V2,T2)

$$\boxed{\left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma-1}}$$

n= 1 mol

$$T = \frac{pV}{R} \Rightarrow \left(\frac{p_2}{p_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow \boxed{p_1V_1^{\gamma} = p_2V_2^{\gamma}} = \text{constant}$$

For an isothermal process T = constant $\Rightarrow$ pV = constant

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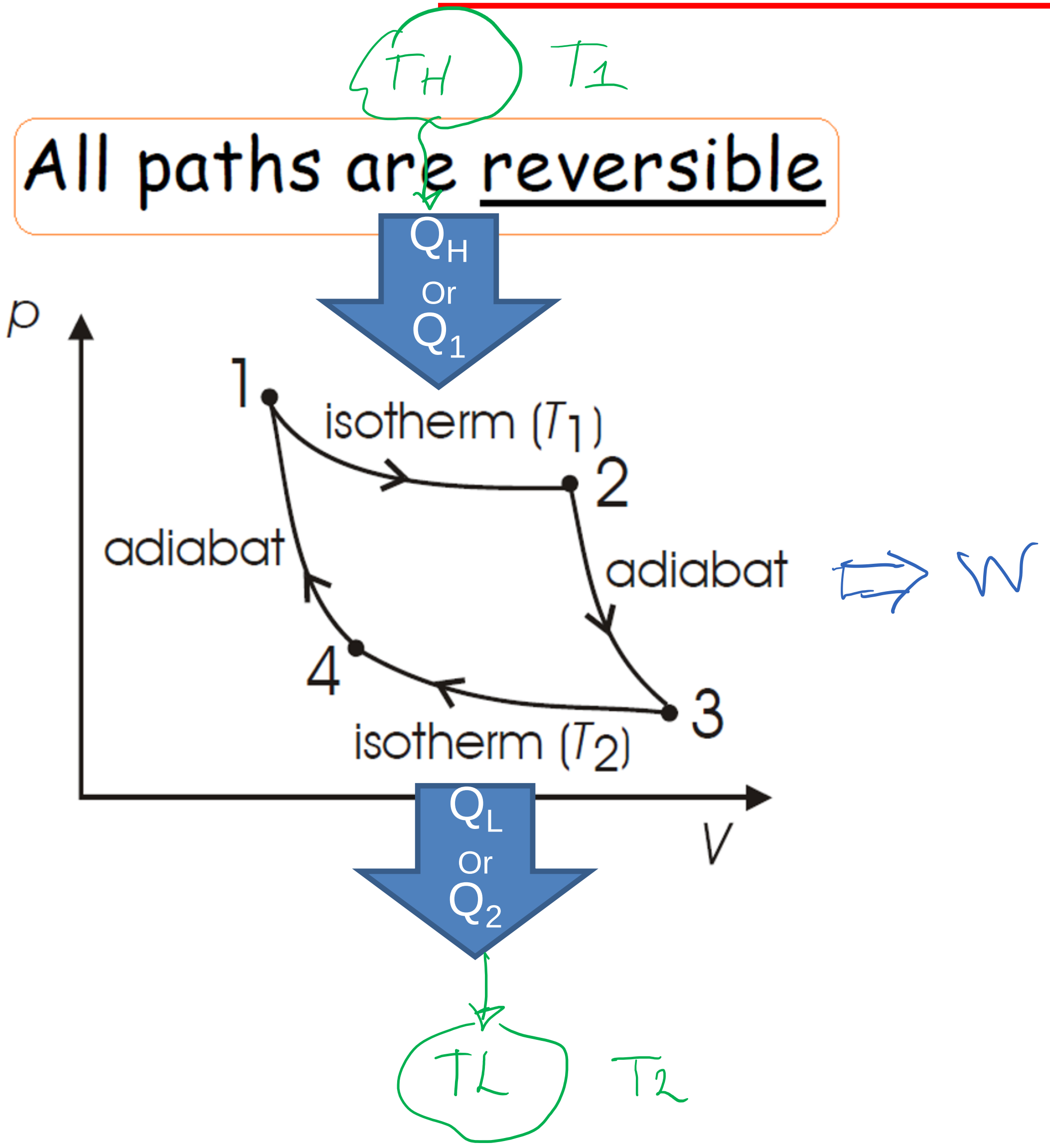
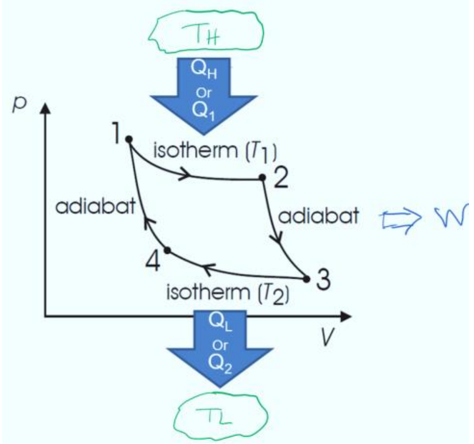
THE CARNOT CYCLE AS **HEAT ENGINE….MASS CONTROL**



Carnot cycle for an ideal gas

_ CONTROL MASS_ 1mol



$\Delta U = Q - W$

$PV = nRT$, cte isot.

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

$\Delta U' = \cancel{Q} - w'$

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

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

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

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

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)

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

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

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

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

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

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

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

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1. THE REVERSE CARNOT CYCLE_ with LV substance

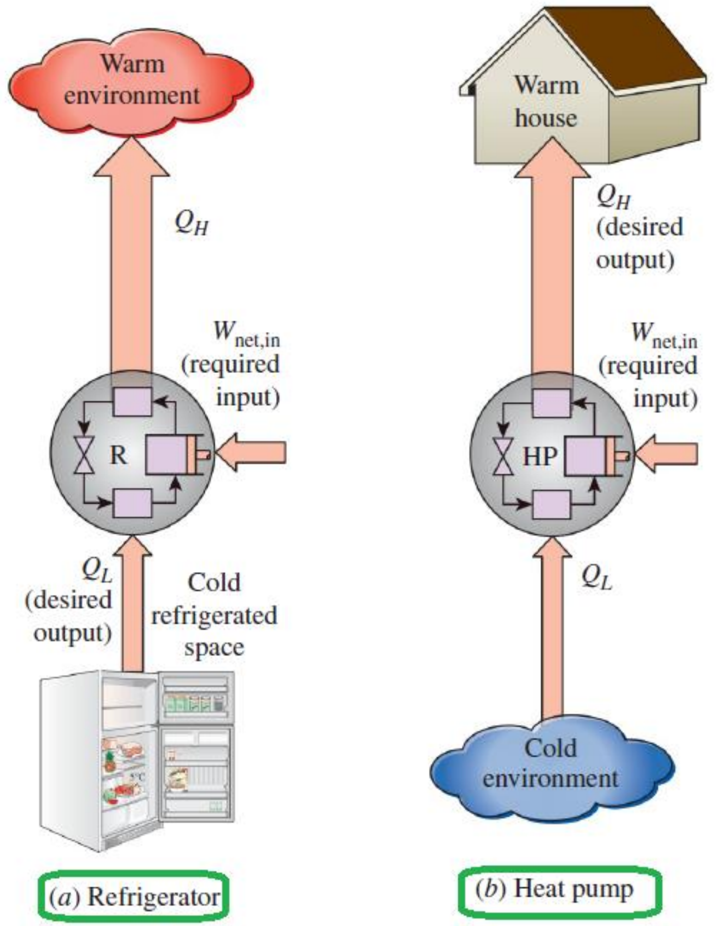
$$COP = \beta_R = \frac{|Q_L|}{|W|} = \frac{|Q_L|}{|Q_H| - |Q_L|} = \frac{1}{\frac{|Q_H|}{|Q_L|} - 1}$$

$$\boxed{\frac{|Q_H|}{T_H} - \frac{|Q_L|}{T_L} = 0} \Rightarrow \boxed{\oint \frac{\delta Q_{rev}}{T} = 0}$$

$$COP = \beta_R = \frac{1}{\frac{T_H}{T_L} - 1}$$

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

$$COP_{HP} = \beta_{HP} = \frac{1}{1 - \frac{T_L}{T_H}}$$



Notice that both COPs increase as the difference between the two temperatures decreases, that is, as *TL* rises or *TH* falls.

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EXAMPLE 1

A company is selling thermic machines that operates between 99.85 °C (cold reservoir) and 199.85 °C (hot reservoir) with the characteristics shown in the table below. Verify if they are possible or not and justify each answer mentioning which thermodynamic statement violates.

Se debe inferir si son entrada o salida para cada equipo

Type / (kW)	$\lvert Q_H \rvert$	$\lvert Q_L \rvert$	$\lvert W \rvert$
Heat pump	100	76	24
Heat engine	100	16	74
Refrigerator	100	0	100
Heat engine	100	85	15
Heat engine	100	0	100
Refrigerator	100	78	22
Heat engine	100	100	0
Heat engine	100	75	25
Refrigerator	100	100	0
Heat pump	100	0	100

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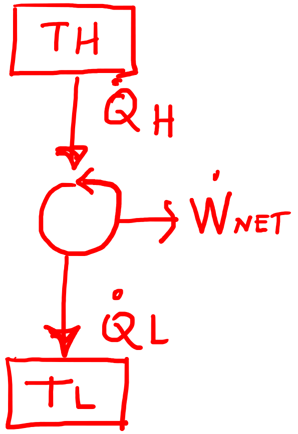
CICLO DE POTENCIA

Masa de control:



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

$$0 = \dot{Q}_H + \dot{Q}_L - \dot{W}_T - \dot{W}_P$$

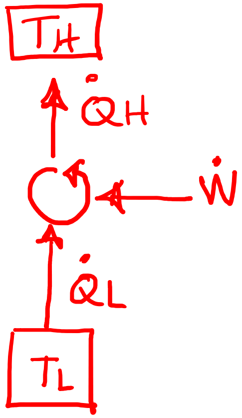
$$0 = |\dot{Q}_H| - |\dot{Q}_L| - |W_T| + |\dot{W}_P|$$

$$|\dot{W}_T| - |\dot{W}_P| = \boxed{|\dot{W}_{NET}| = |\dot{Q}_H| - |\dot{Q}_L|}$$

CICLO DE REFRIGERACION

$\begin{cases} \text{– REFRIGERADOR} \\ \text{– BOMBA DE CALOR} \end{cases}$

Masa de control



$$\cancel{\frac{dE}{dt}} = \dot{Q} - \dot{W} = \dot{Q}_H + \dot{Q}_L - \dot{W}$$

$$0 = |\dot{Q}_H| - |\dot{Q}_L| + |\dot{W}|$$

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

Solution: An operation can be possible only if neither the first and the second law of thermodynamics are violated.

FIRST LAW: $|\boldsymbol{W}| = |\boldsymbol{Q_H}| - |\boldsymbol{Q_L}|$

Type (kW)	|Q_H|	|Q_L|	|W|	Meets the 1st law?	|W| = |Q_H| - |Q_L|
Heat pump	100	76	24	YES	24
Heat engine	100	16	74	NO	84
Refrigerator	100	0	100	YES	100
Heat engine	100	85	15	YES	15
Heat engine	100	0	0	YES	100
Refrigerator	100	78	22	YES	22
Heat engine	100	100	100	YES	0
Heat engine	100	75	25	YES	25
Refrigerator	100	100	100	YES	0
Heat pump	100	0	100	YES	100

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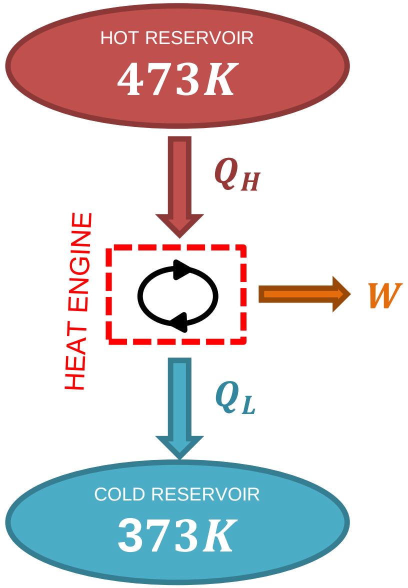
SECOND LAW FOR HEAT ENGINES:

Efficiency of a Heat Engine:

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



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

$$\eta_{rev} = 1 - \frac{373}{473}$$

$$\eta_{rev} = 0.211$$

$\boldsymbol{\eta \leq \eta_{rev}}$ 2nd law for heat engines

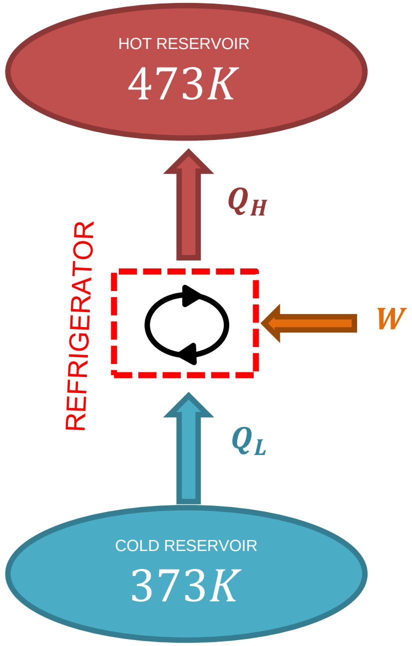
$\boldsymbol{\eta \leq 0.211}$

Type / (kW)	$\lvert Q_H \rvert$	$\lvert Q_L \rvert$	$\lvert W \rvert$	η	Meets the 2nd law?
Heat pump	100	76	24		
~~Heat engine~~	~~100~~	~~16~~	~~84~~	~~0.84~~	~~NO~~
Refrigerator	100	0	100		
Heat engine					
~~Heat engine~~ K-P					
Refrigerator	100	78	22		
Heat engine					
~~Heat engine~~					
Refrigerator	100	100	0		
Heat pump	100	0	100		

<u>SECOND LAW FOR REFRIGERATORS:</u>

COP of a refrigerator:

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



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

$$COP_R^{rev} = \frac{373}{473 - 373}$$

$$COP_R^{rev} = 3.73$$

$$\boxed{COP_R \leq COP_R^{rev}}$$

2nd law for refrigerators

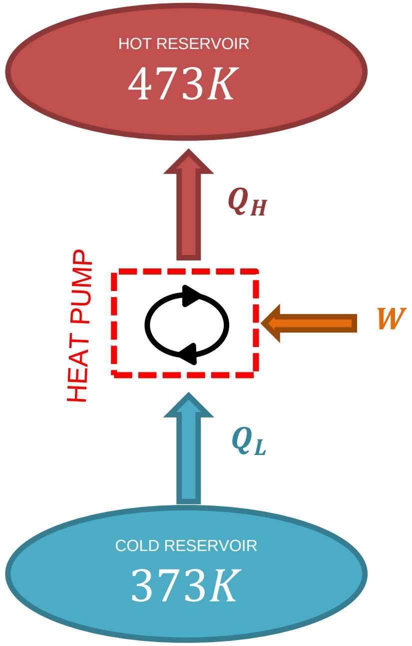
$$\boxed{COP_R \leq \mathbf{3.73}}$$

Type / (kW)	$\lvert Q_H \rvert$	$\lvert Q_L \rvert$	$\lvert W \rvert$	COP	Meets the 2nd law?
Heat pump	100	76	24		
~~Heat engine~~	~~100~~	~~16~~	~~84~~		
Refrigerator	100	0	100	0.00	YES
Heat engine	100	85	15		
~~Heat engine~~	~~100~~	~~0~~	~~100~~		
Refrigerator					
Heat engine	100	100	0		
~~Heat engine~~	~~100~~	~~75~~	~~25~~		
~~Refrigerator~~ clausius					
Heat pump	100	0	100		

SECOND LAW FOR HEAT PUMPS:

COP of a heat pump:

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



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

$$COP_{HP}^{rev} = \frac{473}{473 - 373}$$

$$COP_{HP}^{rev} = 4.73$$

$$COP_{HP} \leq COP_{HP}^{rev}$$

2nd law for heat pumps

$$\boldsymbol{COP_{HP} \leq 4.73}$$

Type / (kW)	$\lvert Q_H \rvert$	$\lvert Q_L \rvert$	$\lvert W \rvert$	COP	Meets the 2nd law?
Heat pump	100	76	24	4.166	YES
~~Heat engine~~	~~100~~	~~16~~	~~84~~		
Refrigerator	100	0	100		
Heat engine	100	85	15		
~~Heat engine~~	~~100~~	~~0~~	~~100~~		
Refrigerator	100	78	22		
Heat engine	100	100	0		
~~Heat engine~~	~~100~~	~~75~~	~~25~~		
~~Refrigerator~~	~~100~~	~~100~~	~~0~~		
Heat pump					

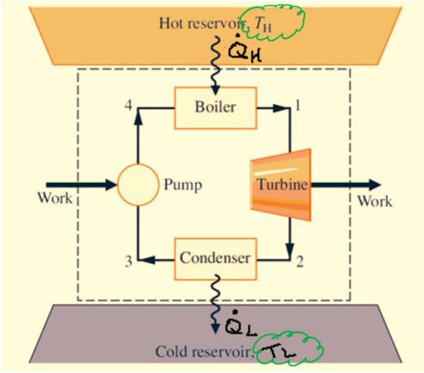
1. THE REVERSE CARNOT CYCLE_ with LV substance

Las ecuaciones ideales derivadas pueden usarse en otros ciclos, con cualquier sustancia gas ideal o no.

Efficiency of a Heat Engine:

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

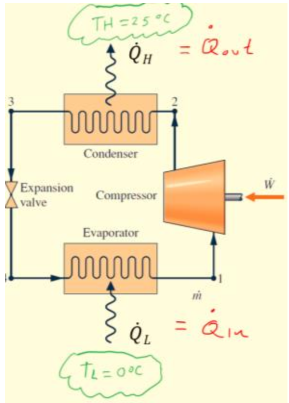
$$\eta_{ideal} = 1 - \frac{T_L}{T_H}$$



COP of a refrigerator:

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

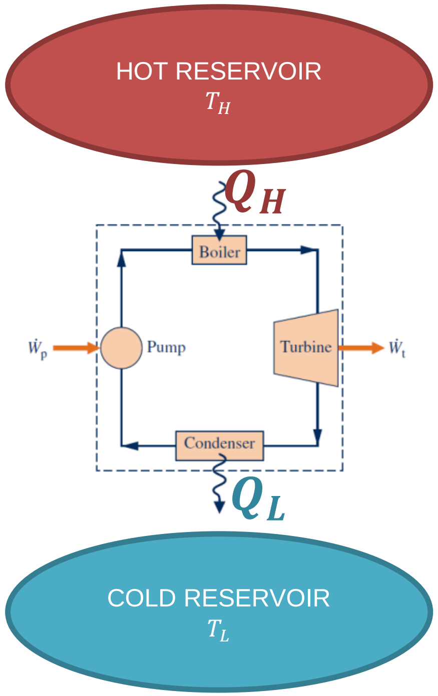
$$COP_R^{ideal} = \frac{|T_L|}{|T_H| - |T_L|}$$

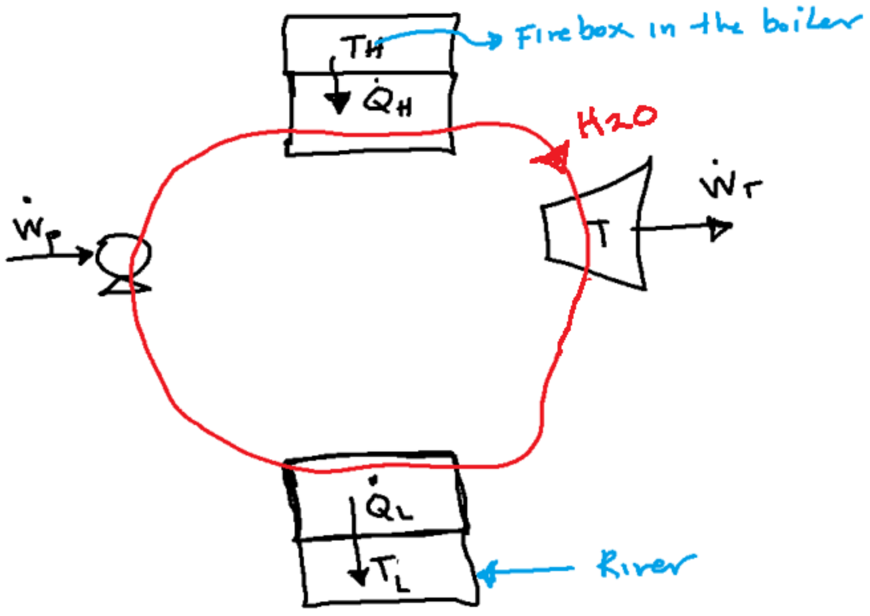


COP of a heat pump:

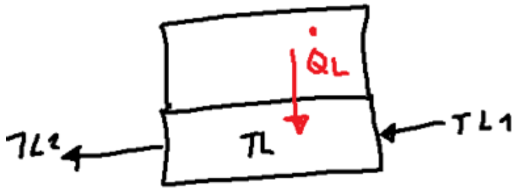
$$COP_{HP} = \beta_{HP} = \frac{|Q_H|}{|W|} = \frac{|Q_H|}{|Q_H| - |Q_L|}$$

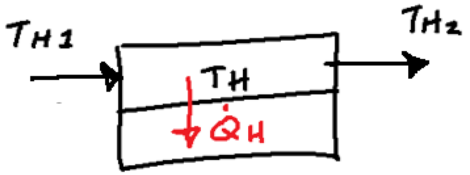
$$COP_{HP}^{ideal} = \frac{|T_H|}{|T_H| - |T_L|}$$





However, in some cycles, either by size or design, T_H and T_L are calculated as an average:





$$T_L = \frac{T_{L1} + T_{L2}}{2}$$

$$T_H = \frac{T_{H1} + T_{H2}}{2}$$

EXAMPLE 2

Una bomba de calor se utiliza para **tomar calor desde un depósito frío a** $358\ K$ y entregarlo a un **depósito caliente** a $423\ K$.

La bomba de calor recibe desde el depósito frío una tasa de calor de:

$$\dot{Q}_L = 5\ MW$$

El coeficiente de desempeño real de la bomba de calor es:

$$COP_{HP} = 2.5$$

Con esta información, determine:

a) La potencia que debe suministrarse a la bomba de calor para que opere:

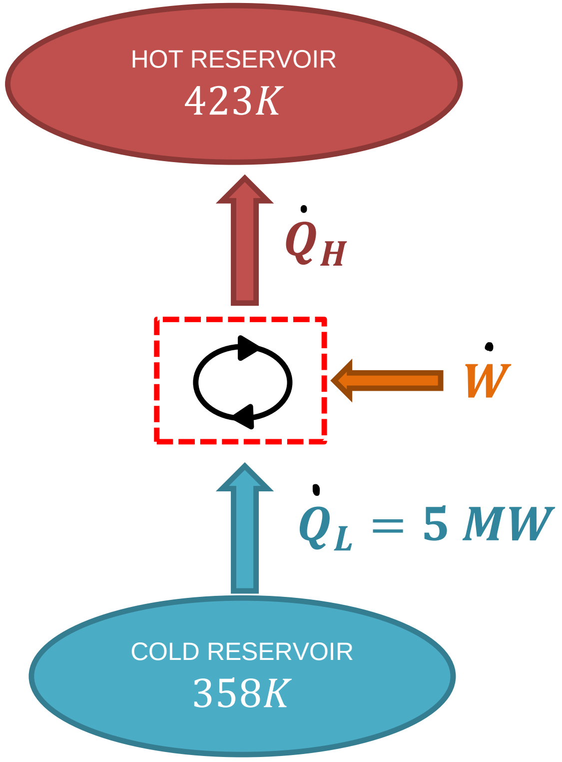
$$|\dot{W}| = ?\quad [MW]$$

b) Si una bomba de calor de Carnot tuviera el mismo valor de $COP_{HP} = 2.5$ y trabajara con el mismo depósito frío:

$$T_L = 358\ K$$

¿cuál tendría que ser la temperatura del depósito caliente?

$$T_H = ?\quad [K]$$



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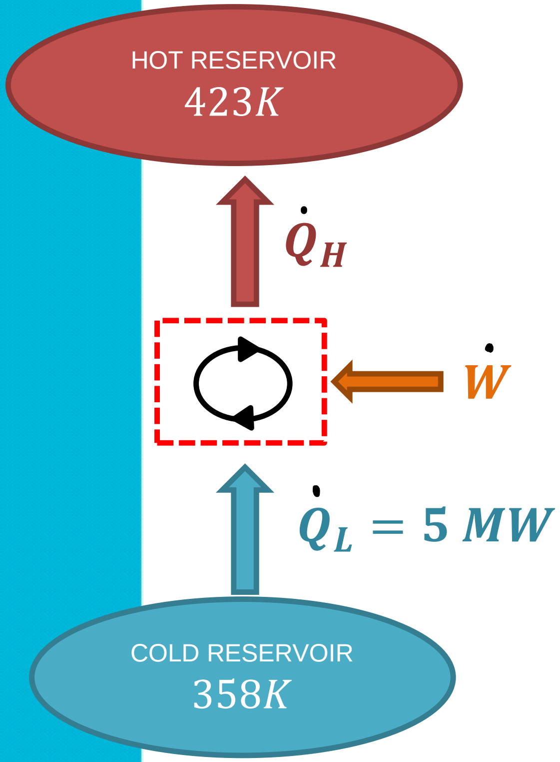
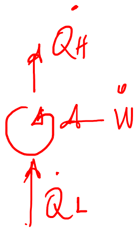
EXERCISE 2





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

$$0 = \dot{Q}_H + \dot{Q}_L - \dot{W}$$

$$\dot{Q}_H < 0 \quad \dot{Q}_L > 0 \quad \dot{W} < 0$$

$$0 = -|\dot{Q}_H| + |\dot{Q}_L| + |\dot{W}|$$

$$|\dot{Q}_H| = |\dot{Q}_L| + |\dot{W}|$$

a) The power required is:

$$\mathrm{COP_{HP}} = \frac{|Q_H|}{|W|} \rightarrow 2.5 = \frac{|Q_L| + |W|}{W}$$

$$2.5 = \frac{5 + |W|}{|W|}$$

$$\boxed{|\dot{W}| = 3.333\ MW}$$

b) The Carnot temperature:

$$\mathrm{COP_{HP}} = \frac{T_H}{T_H - T_L} \rightarrow 2.5 = \frac{T_H}{T_H - 358}$$

$$\boxed{T_H = 596.667K}$$

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