

Thermodynamic_2026_1

Second Law_S10_2

NEDHER SANCHEZ RAMIREZ
NAUDY LOPEZ



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 capítulo
- 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.

Thermodynamics _ Evaluation

S_B

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

SEMANA 1	TAREA VIRTUAL	SE CALIFICA AUTOMATICO NO NECESITA PROCEDIMIENTO
SEMANA 2	TAREA VIRTUAL	
SEMANA 3	TAREA VIRTUAL	
		TAREA INDIVIDUAL: Esta parte incluye subir un archivo con la solución
SEMANA 4	TAREA INDIVIDUAL 1 + EVALUACION_AULA1	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	
	EVALUACION_AULA4+TAREA INDIVIDUAL 3 +Tarea grupal 1	
SEMANA 9		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	
	EVALUACION_AULA6	
SEMANA 14		EVALUACION_AULA : SEMANAS 1-13
SEMANA 15		
SEMANA 16	FINAL	

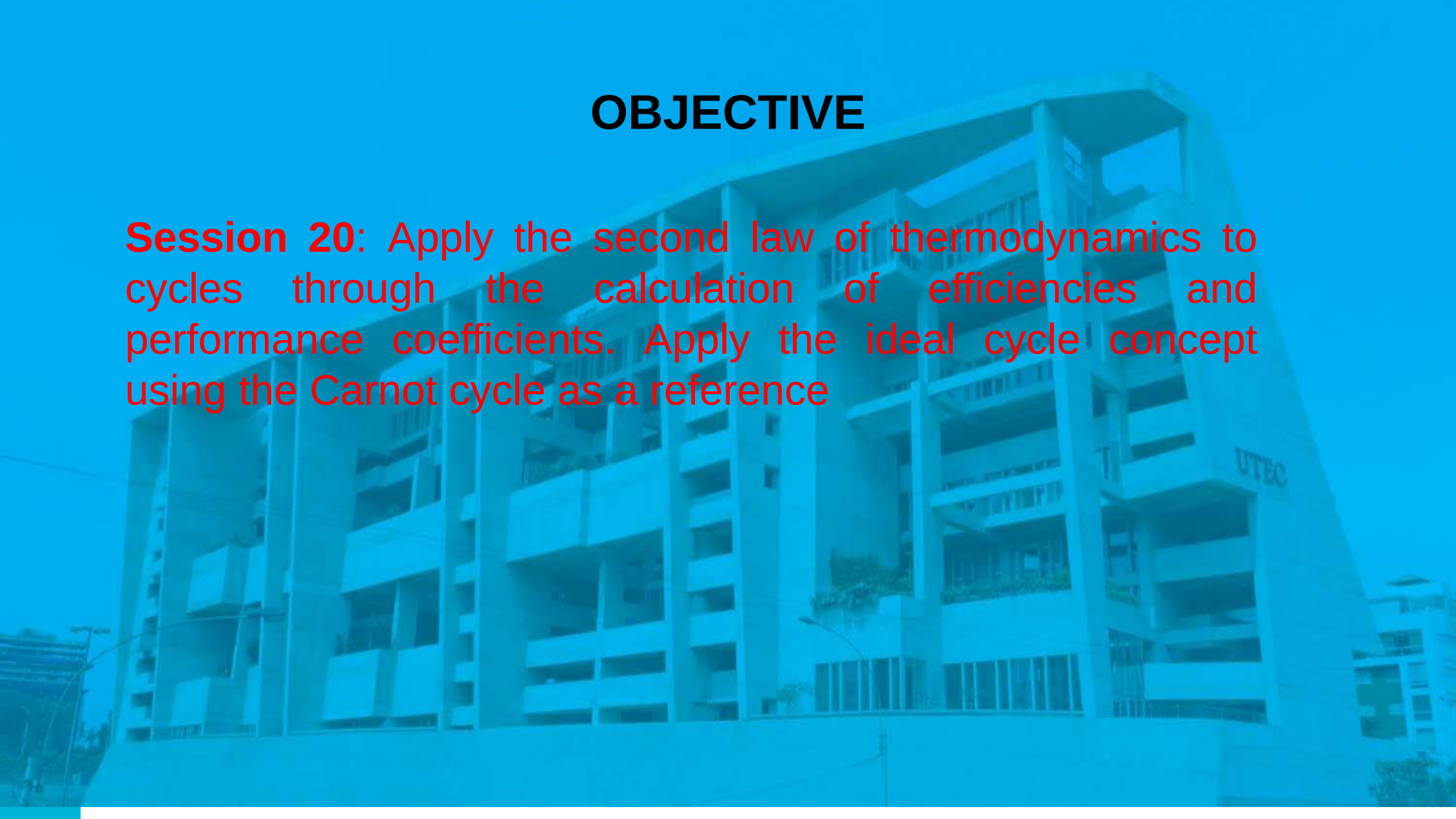
COMPONENTE	%
PARCIAL	20
FINAL	30
C	50
APROBACIÓN: 11/20	

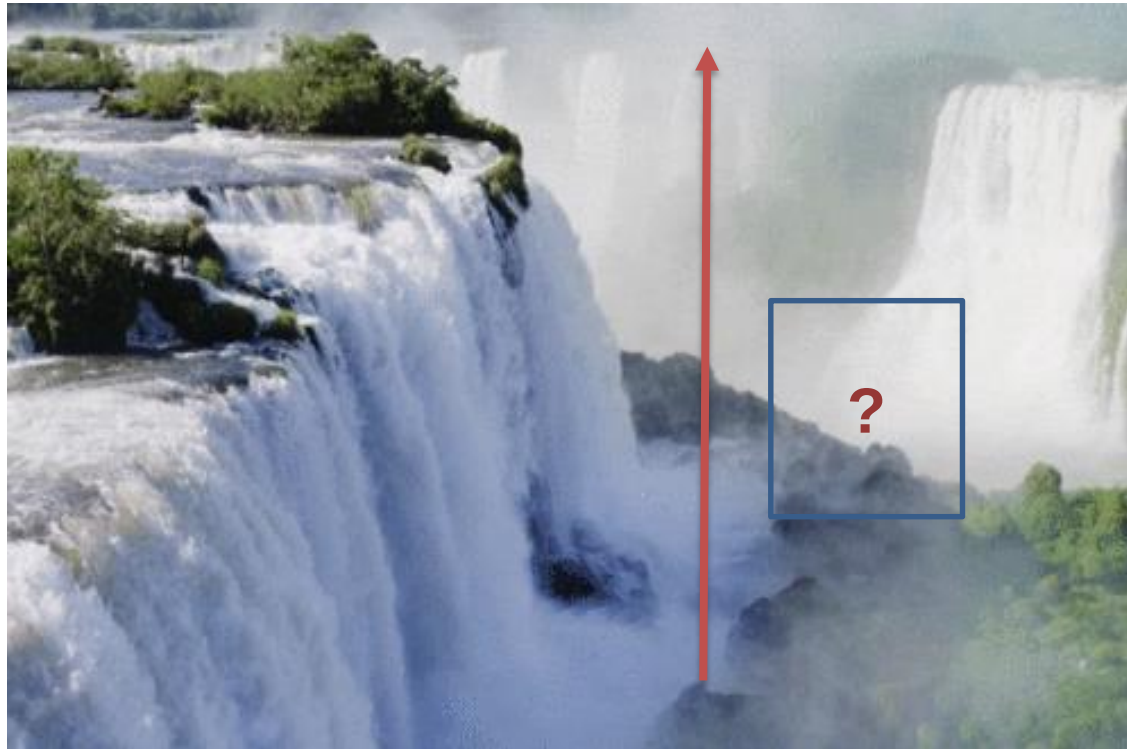
***LAS TAREAS VIRTUALES O LOS GRADESCOPE (TAREA INDIVIDUAL) se abren lunes 2pm y se cierran sábado media noche. La tarea virtual se presenta hasta un máximo de 3 veces.**

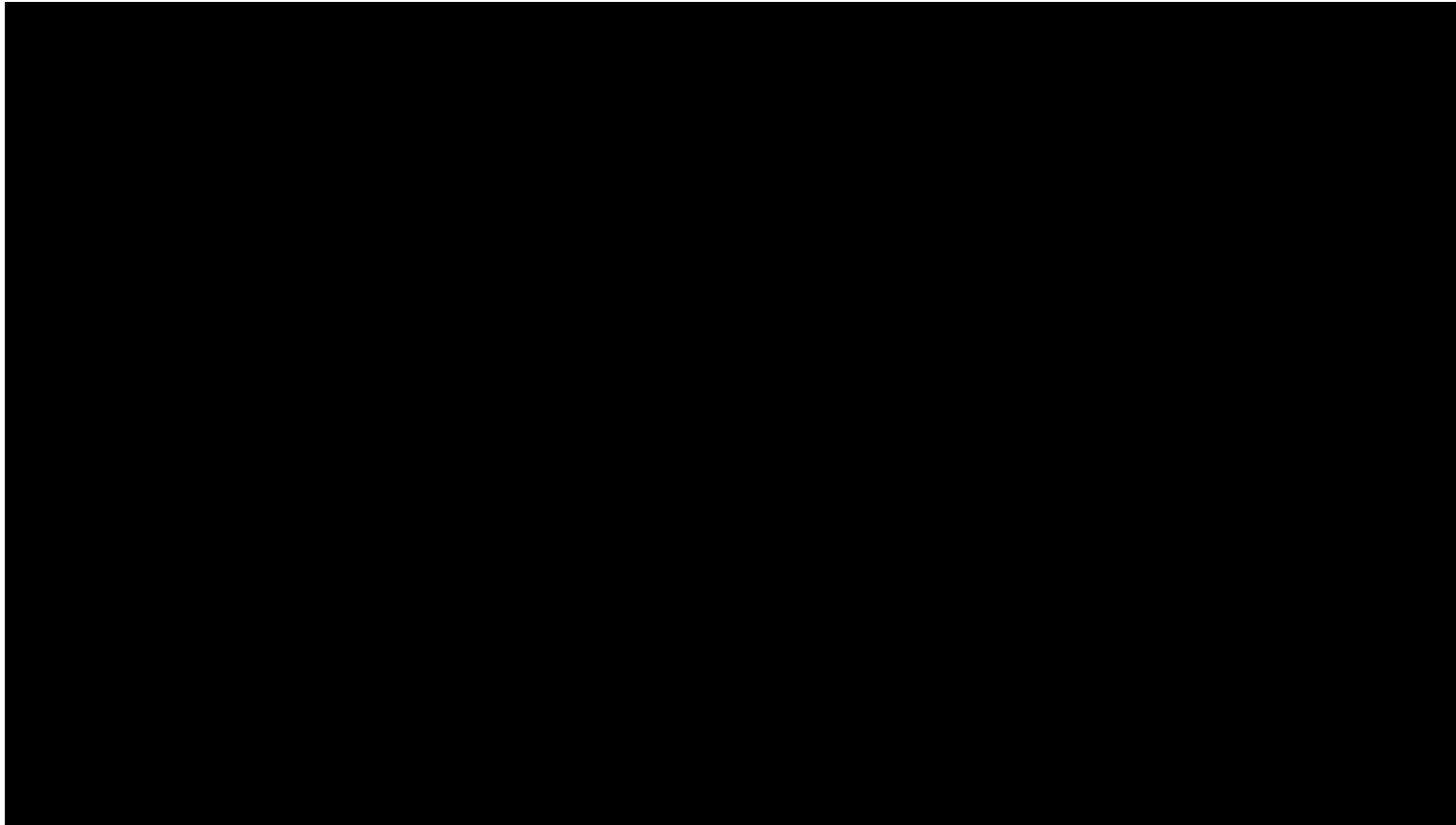
EVALUACION_AULA: es un quiz de 20 min aprox. en aula.

OBJECTIVE

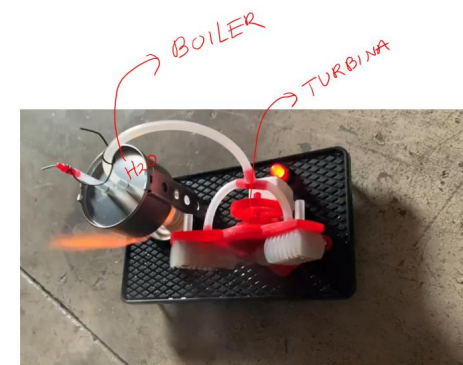
Session 20: Apply the second law of thermodynamics to cycles through the calculation of efficiencies and performance coefficients. Apply the ideal cycle concept using the Carnot cycle as a reference



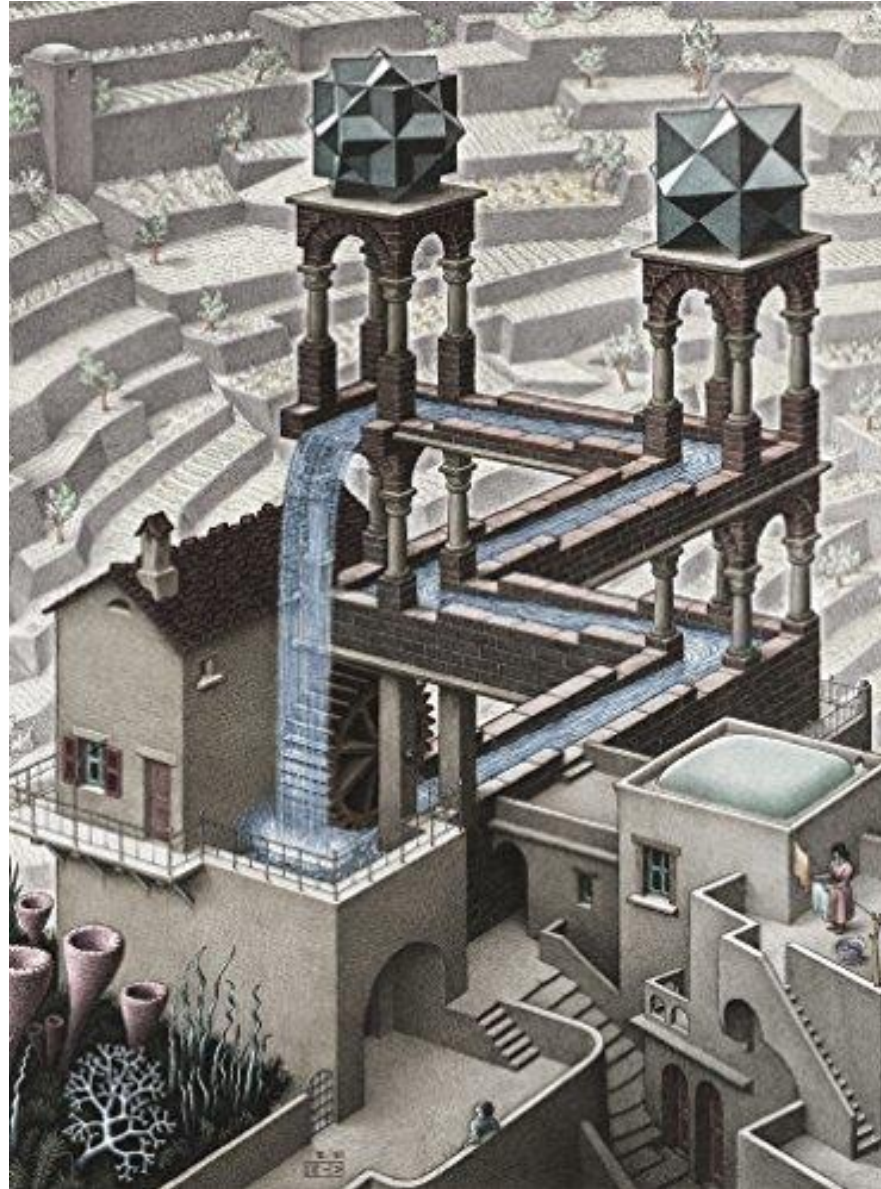


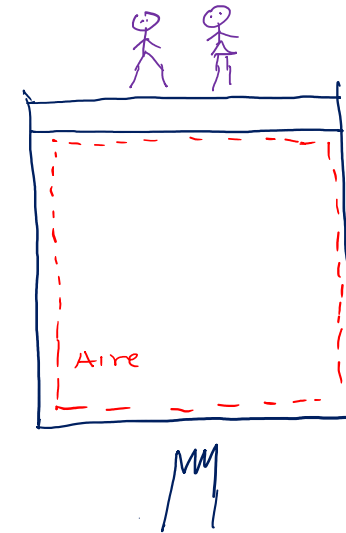
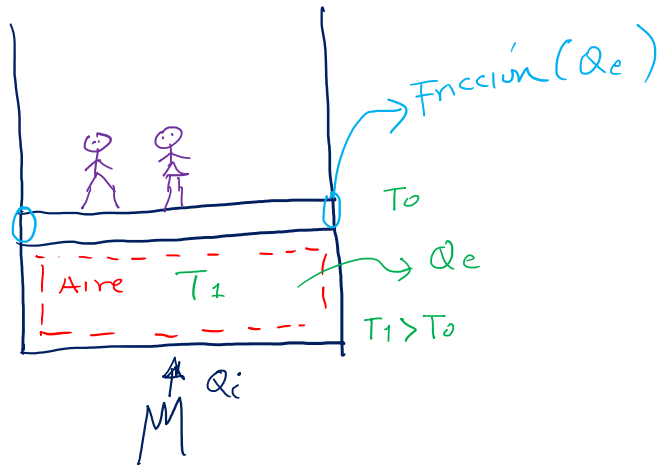


https://www.youtube.com/watch?v=dpws6saii9k&ab_channel=PROFESSORPARDALBRASIL



M.C. Escher





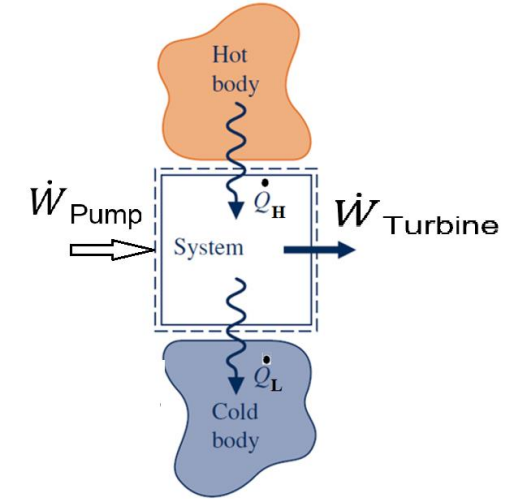
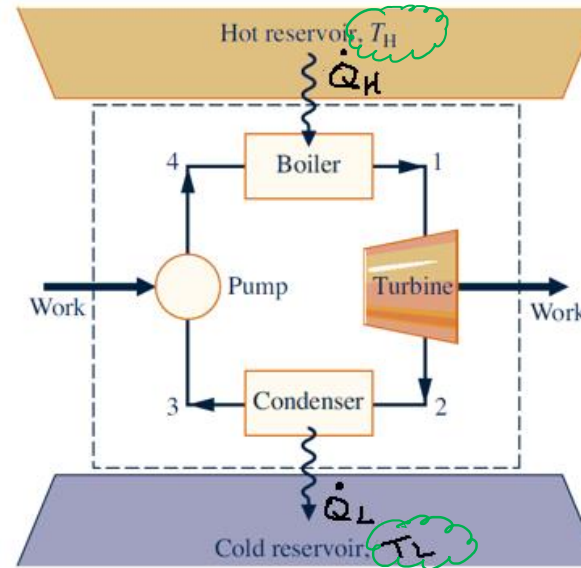
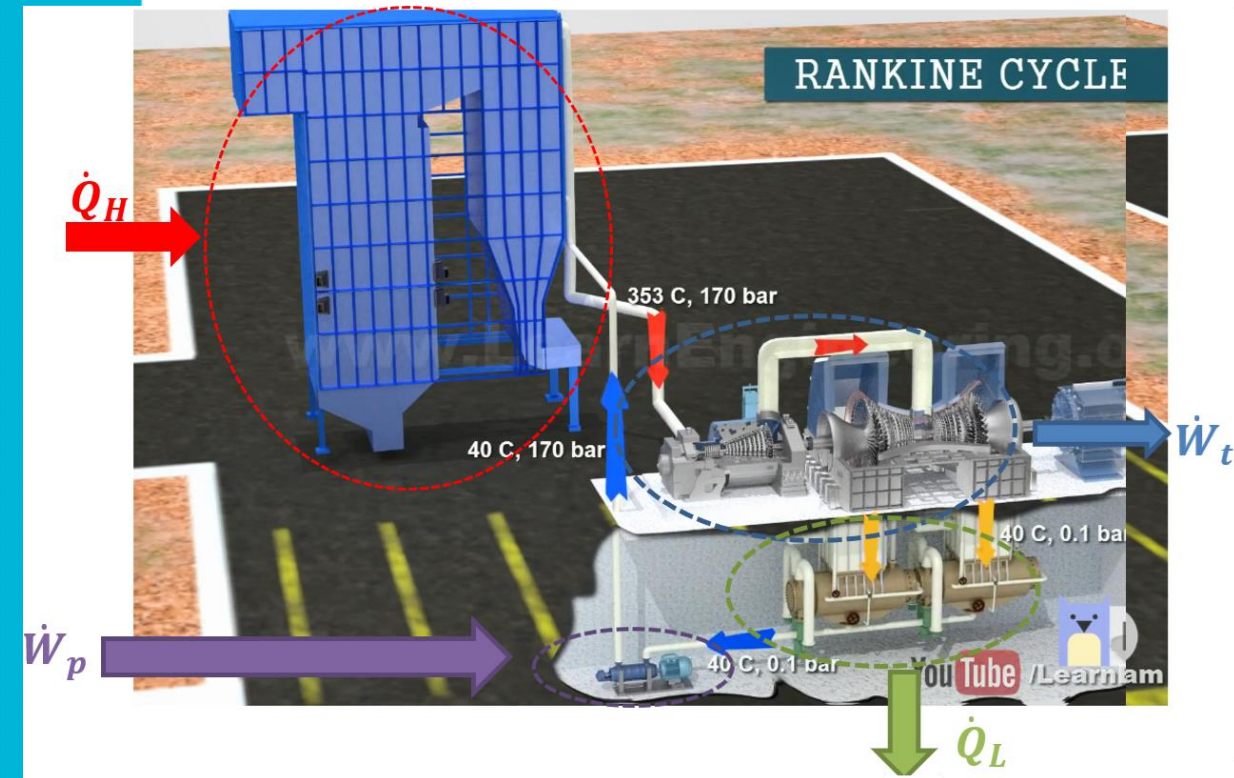
$$\Delta U = Q_{NET} - W_{NET}$$

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

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

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

RANKINE CYCLE

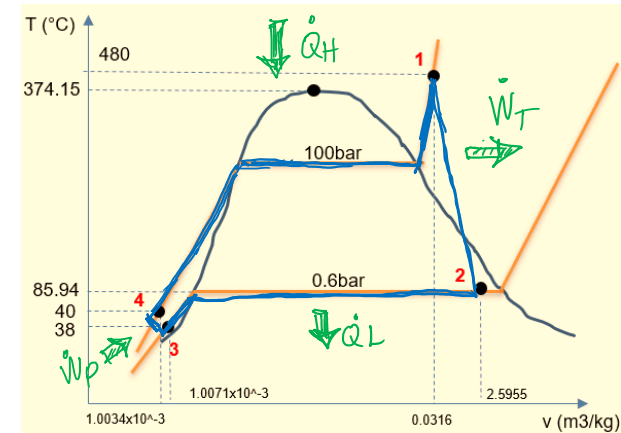


$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

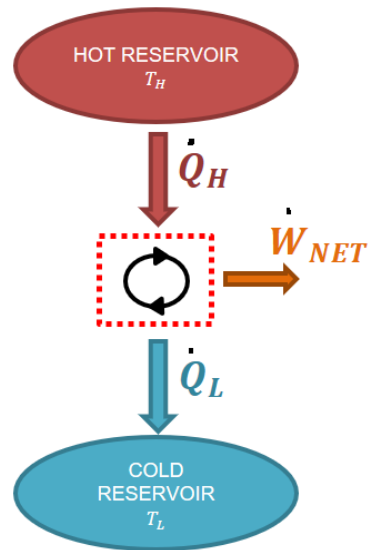
$$\dot{Q}_{NET} = \dot{Q}_H + \dot{Q}_L = \dot{W}_{NET}$$

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

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



CONCEPTS : 2nd LAW (K-P) statement



Efficiency of a Heat Engine

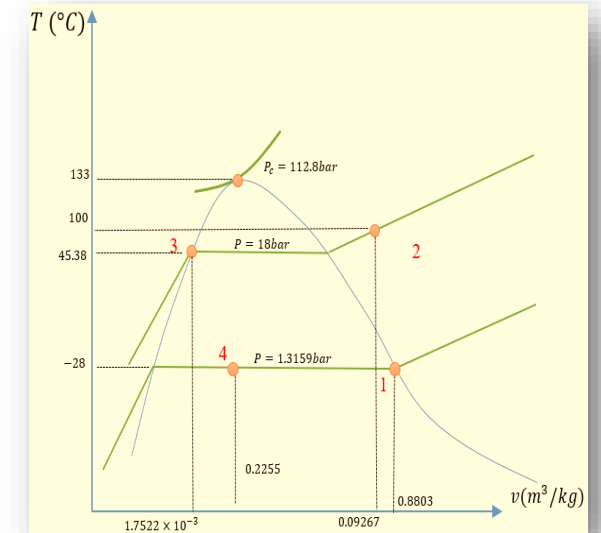
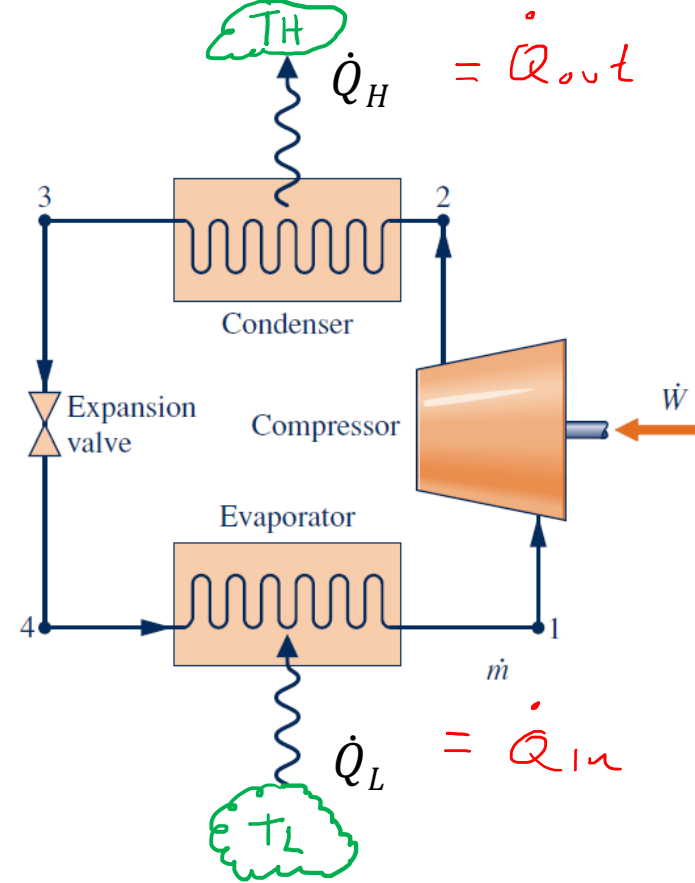
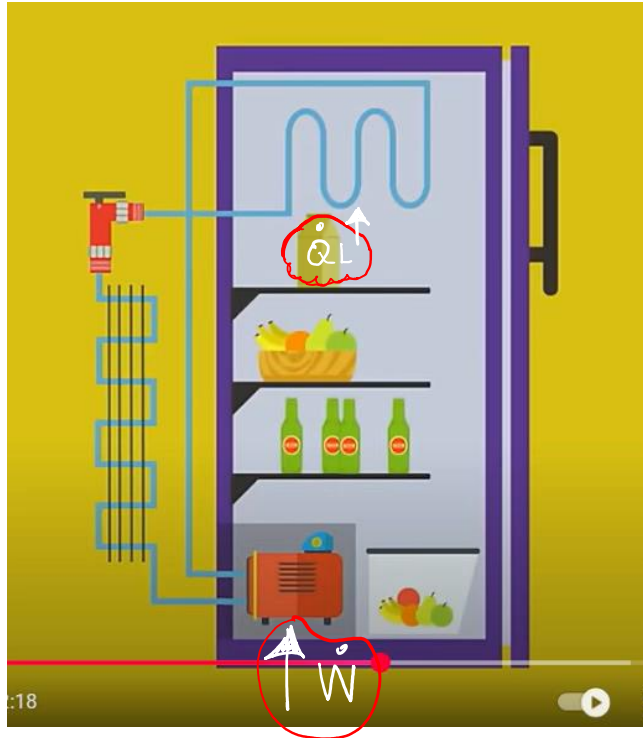
$$\eta = \frac{|\dot{W}_{NET}|}{|\dot{Q}_H|} = \frac{\text{Want}}{\text{Cost}}$$

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

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!

Refrigeration cycle



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

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

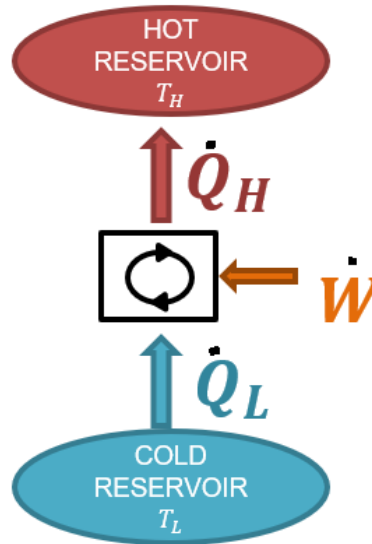
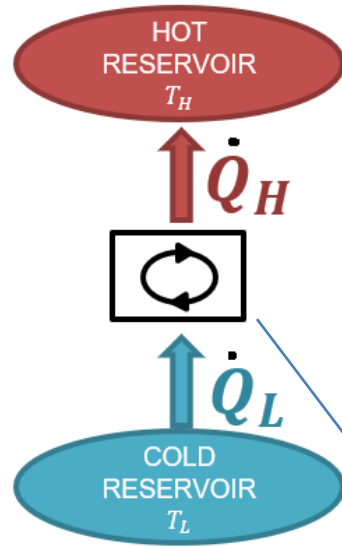
$$COP_R = \beta_R = \frac{|\dot{Q}_L|}{|\dot{W}|} = \frac{|\dot{Q}_L|}{|\dot{Q}_H| - |\dot{Q}_L|}$$

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

E.E.

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

CONCEPTS : 2nd LAW Clausius statement (C)



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

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

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

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

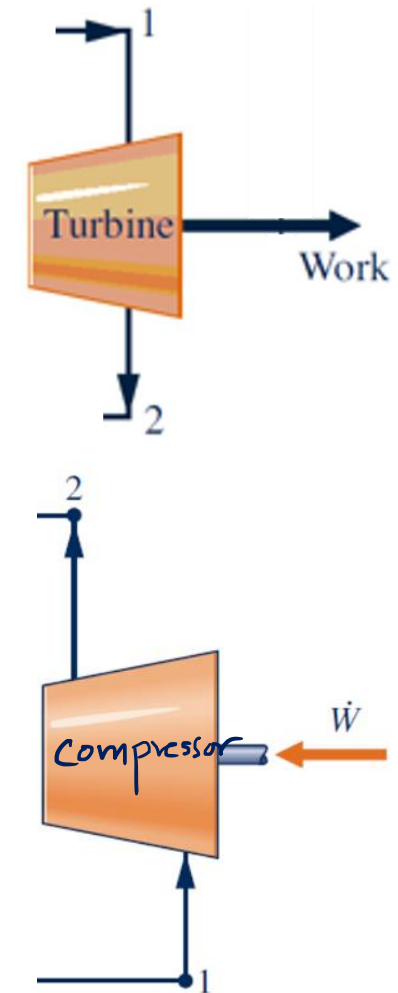
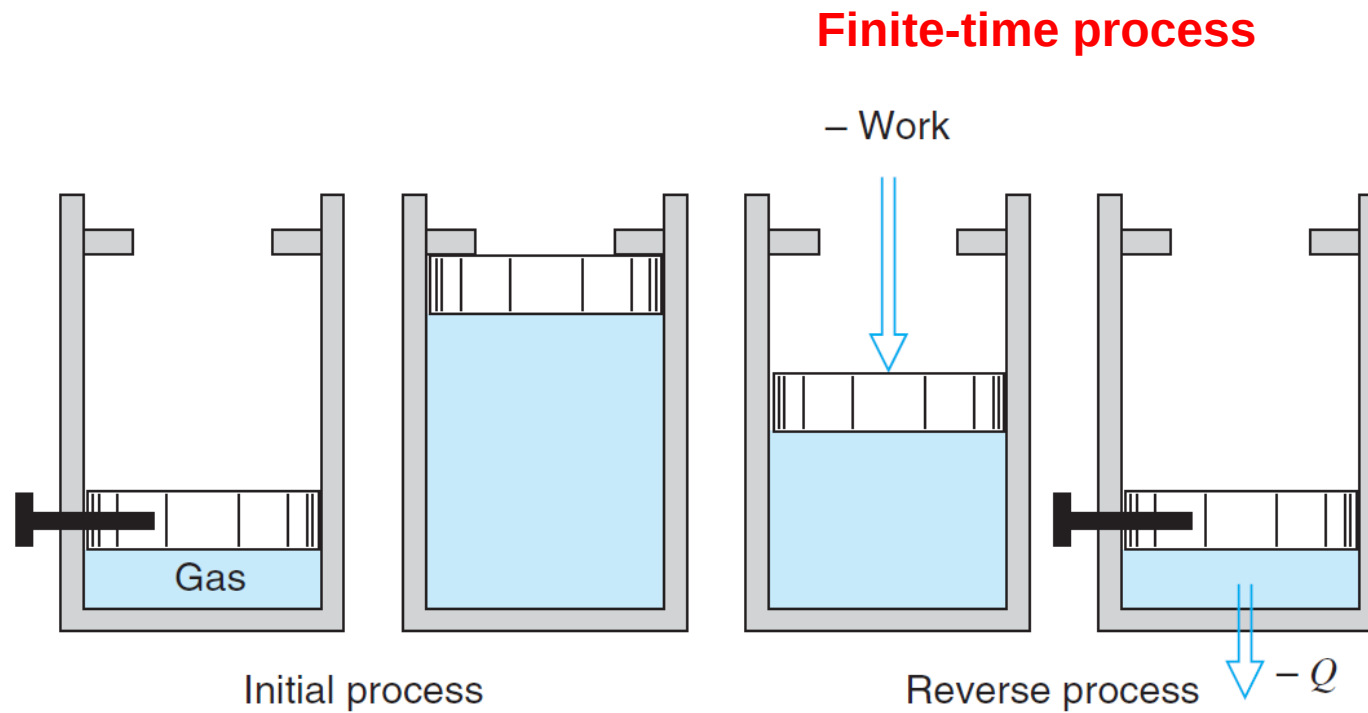
A process that can be reversed, returning both the system and the surroundings to their original states

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?

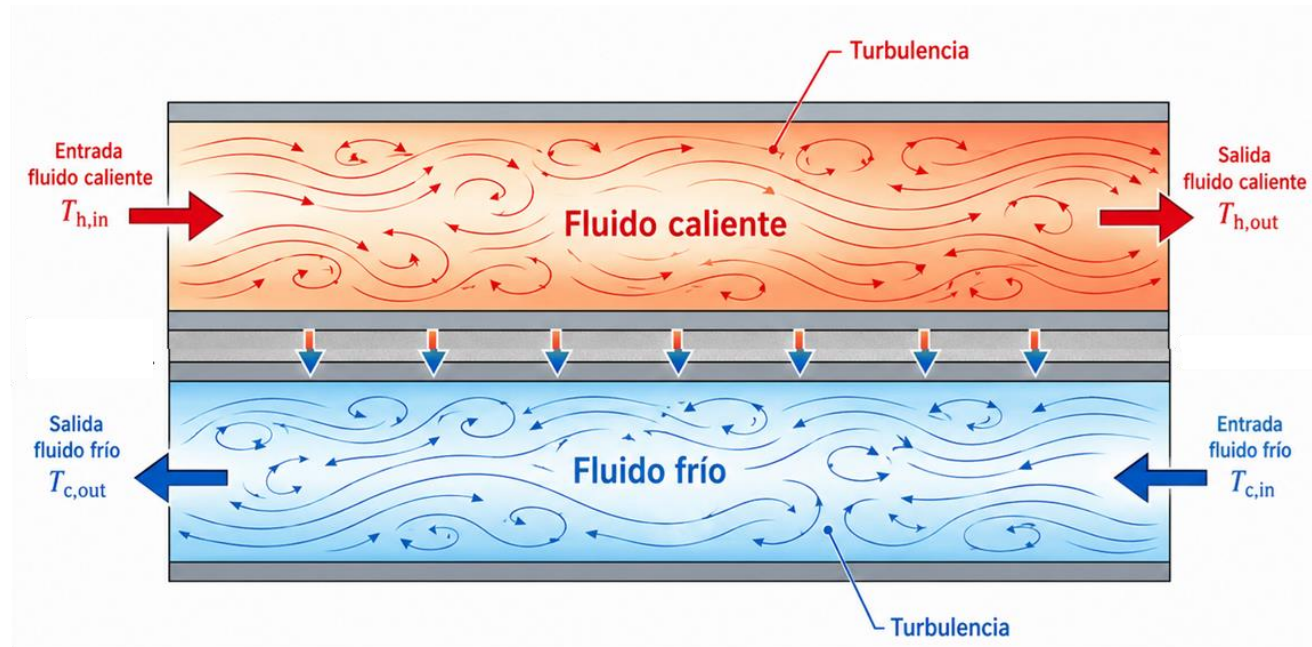


FACTORS THAT RENDER PROCESSES IRREVERSIBLE

Friction

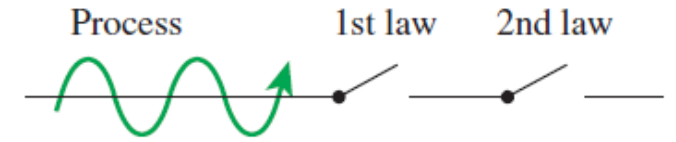


Irreversibility due to finite temperature difference



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, **the second law of thermodynamics**.



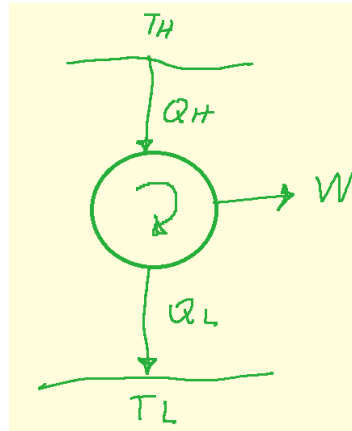
<https://www.youtube.com/watch?v=bCk4pEY5Mdk>

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)

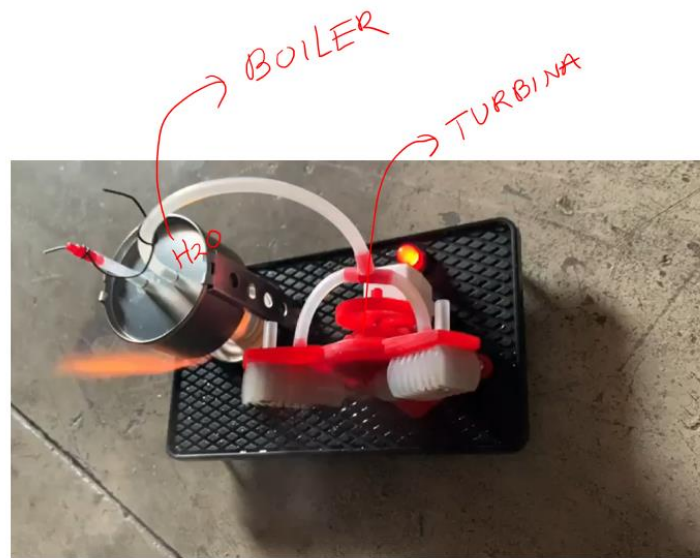


$$h(240^{\circ}\text{C}, 1\text{bar}) \approx 100 \frac{\text{kJ}}{\text{kg}} \quad (\text{L.C} \approx \text{L.S})$$

$$h(240^{\circ}\text{C}, 1\text{bar}) \approx 3000 \frac{\text{kJ}}{\text{kg}} \quad (\text{v.s.c})$$

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

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



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?

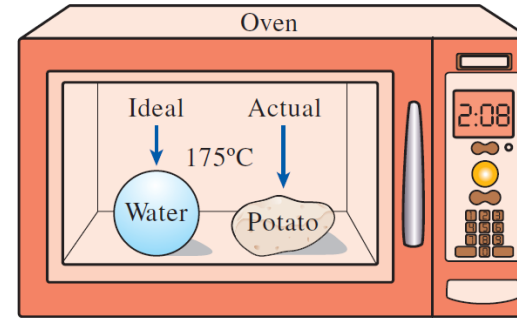


FIGURE Modeling is a powerful engineering tool that provides great insight and simplicity at the expense of some loss in accuracy.

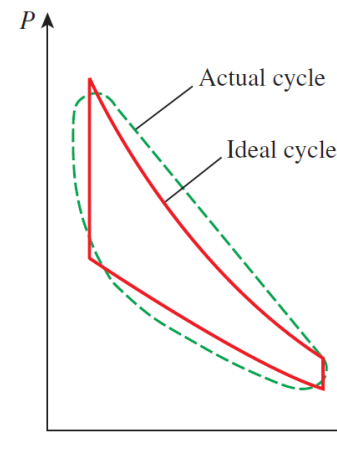
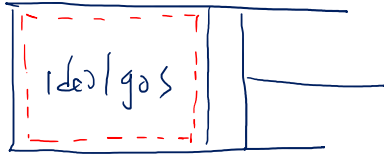
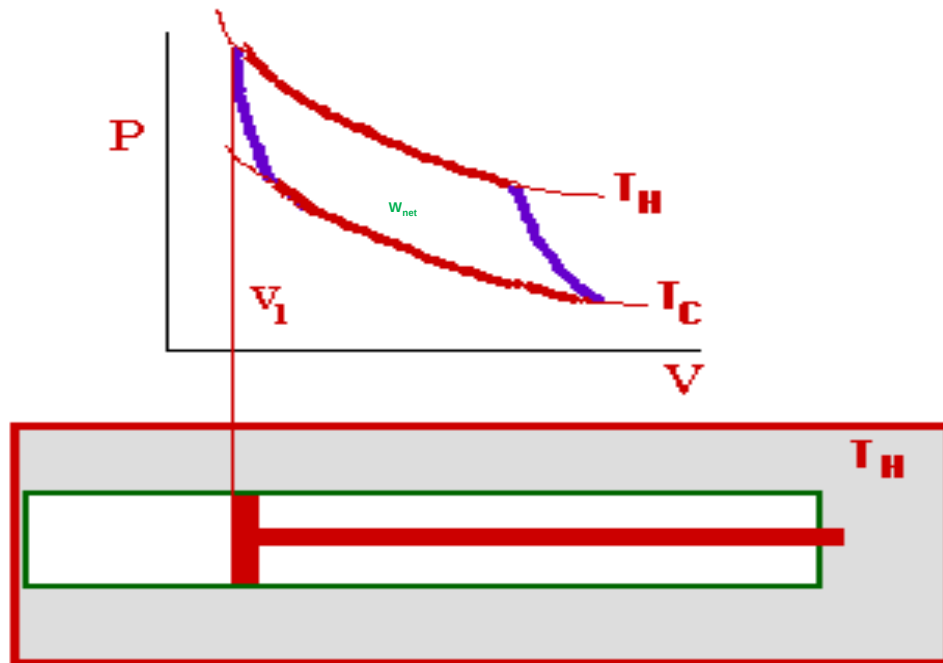


FIGURE The analysis of many complex processes can be reduced to a manageable level by utilizing some idealizations.

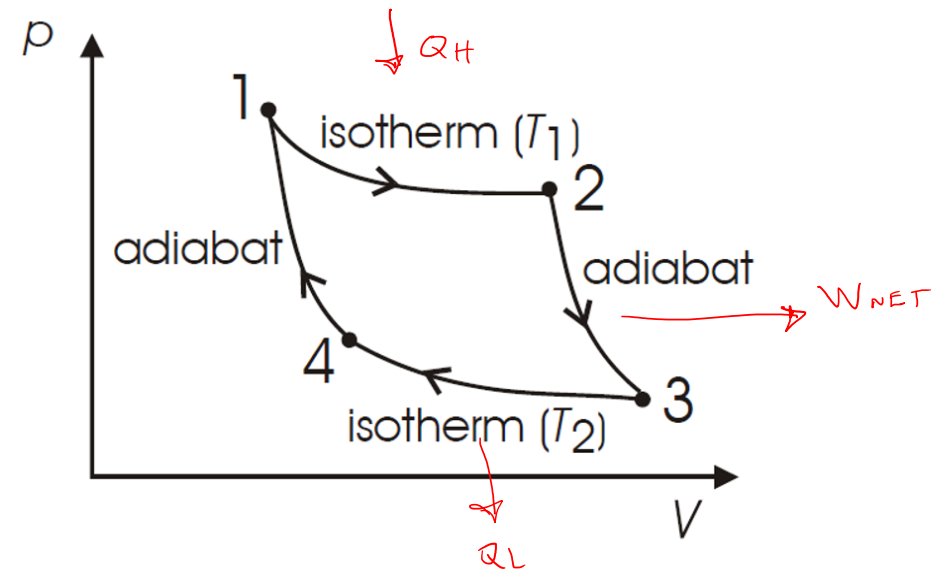


CARNOT_Ideal gas (W_{rev})



$$T_C = T_L$$

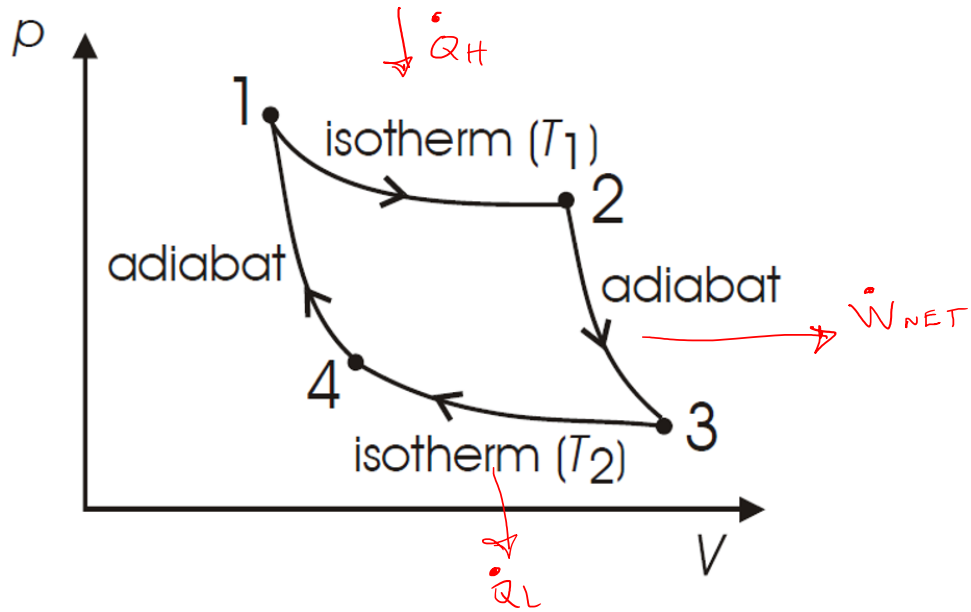
All paths are reversible



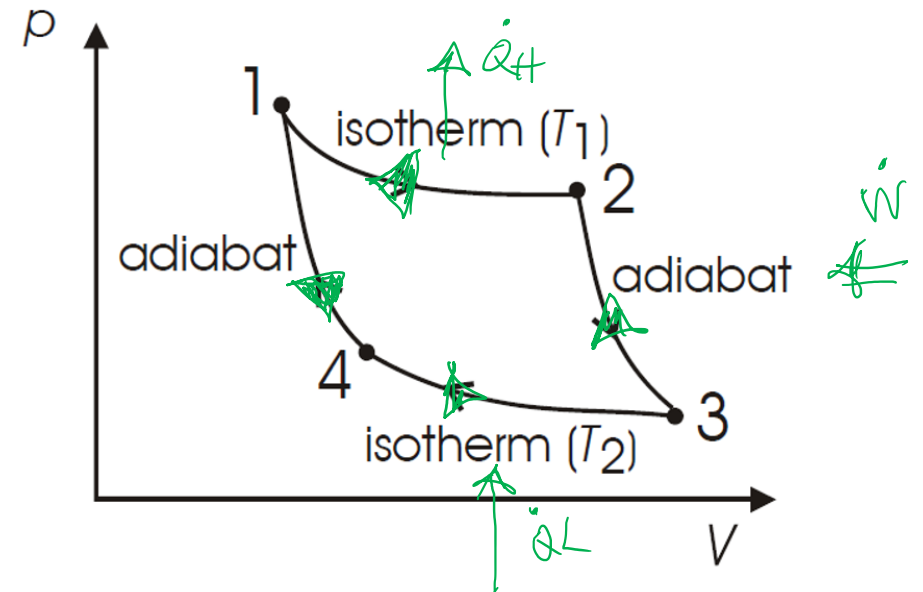
power cycle ?

CARNOT_Ideal gas (W_{rev})

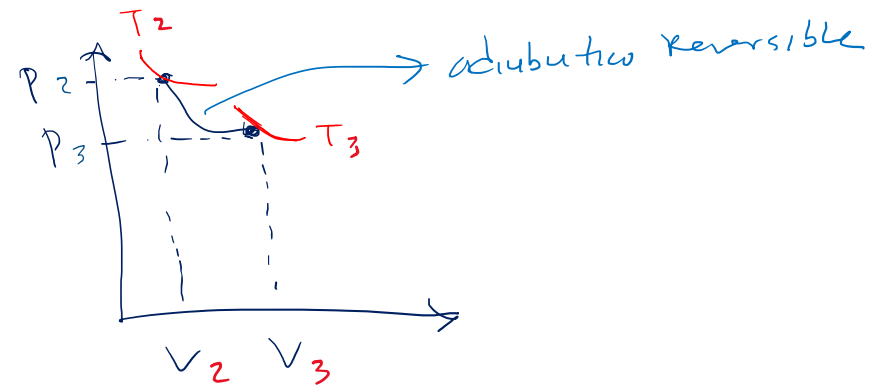
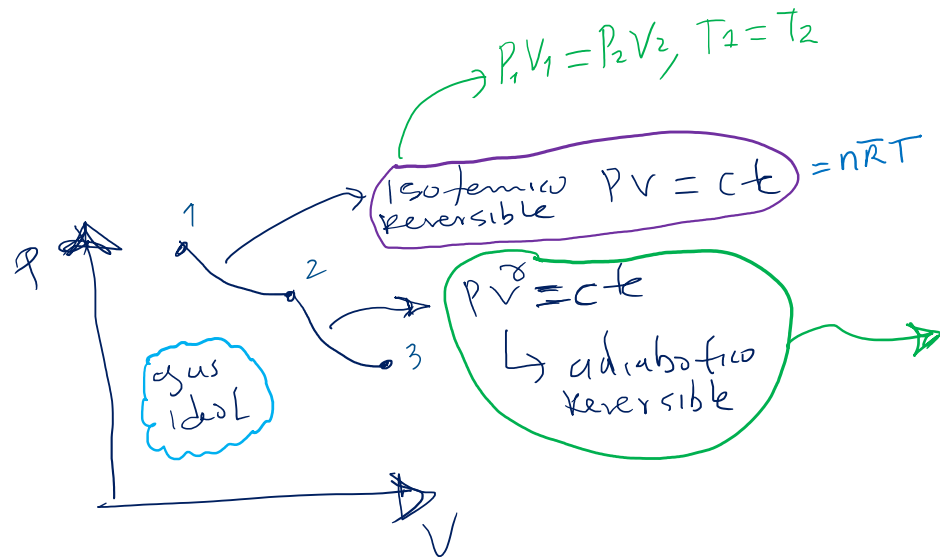
All paths are reversible



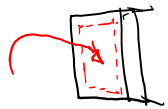
All paths are reversible



Power or Refrigeration cycle?



$$P_2 V_2^\gamma = P_3 V_3^\gamma, \quad \gamma = \frac{C_P}{C_V}, \quad \frac{T_3}{T_2} = \left(\frac{V_2}{V_3} \right)^{\gamma-1}$$



Reversible Adiabatic Expansion (or compression) of an Ideal Gas

1 mole gas (p_1, V_1, T_1) = 1 mole gas (p_2, V_2, T_2)

Demonstrate

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

$$p_1 V_1^\gamma = p_2 V_2^\gamma = \text{constant}$$

Considerations:

$$\text{adiabatic} \Rightarrow \delta Q = 0$$

$$\text{Ideal gas} \Rightarrow dU = C_v dT$$

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

$$dU = -pdV \quad [\text{KJ}]$$

$$\bar{C}_v dT = -pdV \text{ along path}$$

$$\stackrel{\Rightarrow}{p = \frac{\bar{R}T}{V}} \bar{C}_v \frac{dT}{T} = -\bar{R} \frac{dV}{V}$$

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

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

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

Reversible Adiabatic Expansion (or compression) of an Ideal Gas

1 mole gas $(p_1, V_1, T_1) = 1 \text{ mole gas } (p_2, V_2, T_2)$

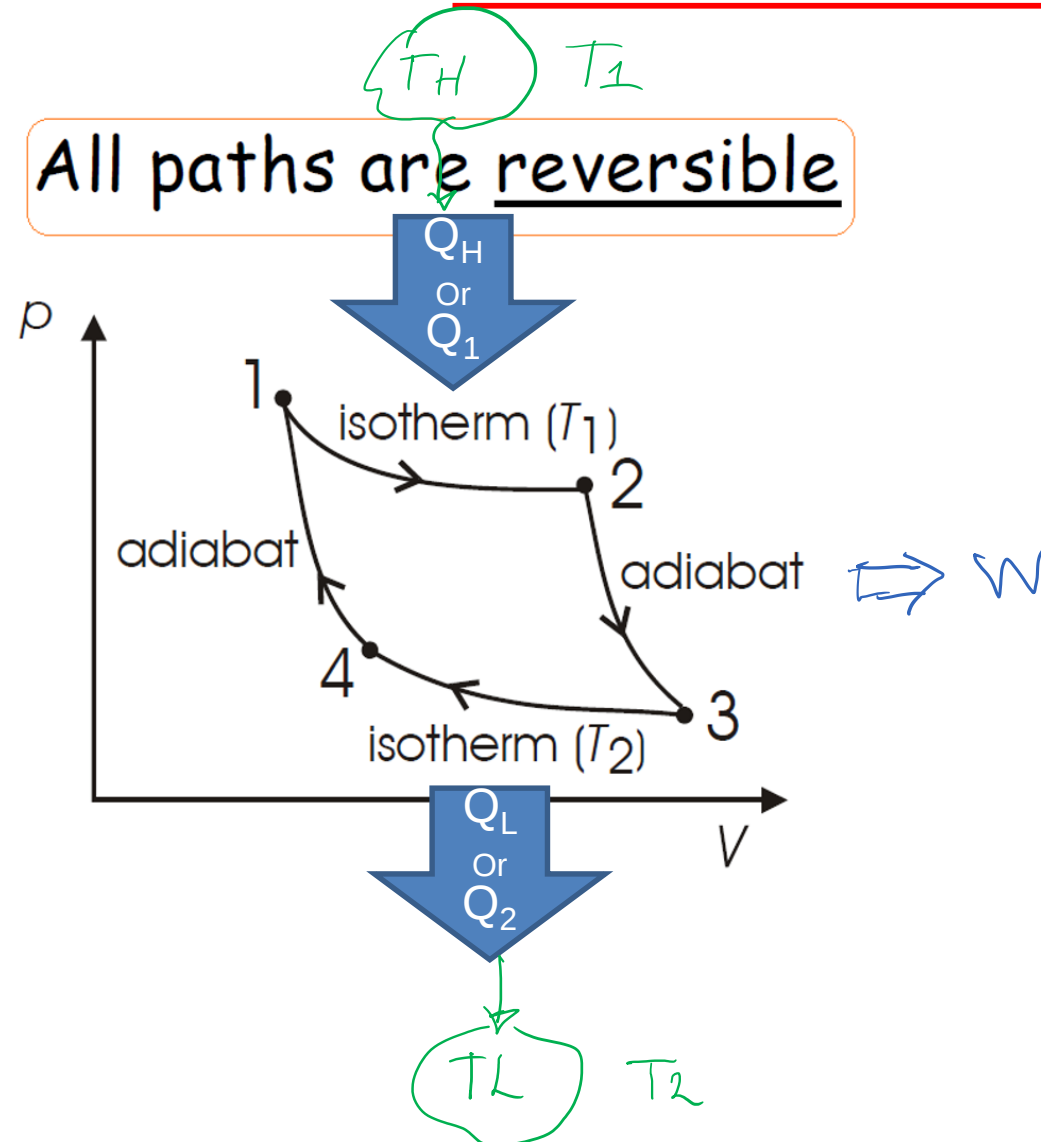
$$\left(\frac{T_2}{T_1} \right) = \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

$$\eta = 1 \text{ mol}$$

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

For an isothermal process $T = \text{constant} \Rightarrow pV = \text{constant}$

THE CARNOT CYCLE AS HEAT ENGINE...MASS CONTROL



Carnot cycle for an ideal gas

CONTROL MASS 1mol

$\Delta U = Q - W$

$1 \rightarrow 2$ $\Delta U = 0$; $Q_1 = w_1 = \int_1^2 p dV = \bar{R} T_1 \ln\left(\frac{V_2}{V_1}\right)$
 $\Delta U = Q - W$

$2 \rightarrow 3$ $Q = 0$; $-w'_1 = C_V (T_2 - T_1)$

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

$3 \rightarrow 4$ $\Delta U = 0$; $Q_2 = w_2 = \int_3^4 p dV = \bar{R} T_2 \ln\left(\frac{V_4}{V_3}\right)$

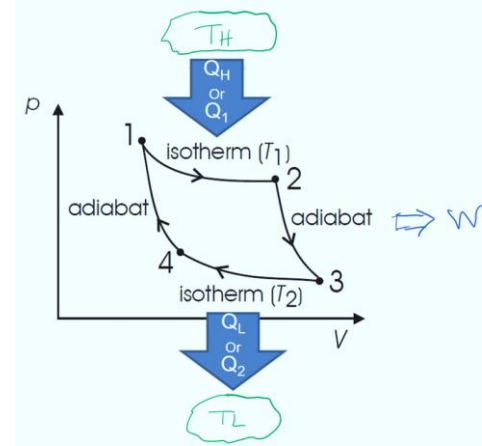
$4 \rightarrow 1$ $Q = 0$; $-w'_2 = C_V (T_1 - T_2)$

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

$$\frac{Q_2}{Q_1} = \frac{T_2 \ln(V_4/V_3)}{T_1 \ln(V_2/V_1)}$$

$$\left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{T_2}{T_1}\right) = \left(\frac{V_2}{V_3}\right)^{\gamma-1} \Rightarrow \left(\frac{V_4}{V_3}\right) = \left(\frac{V_1}{V_2}\right) \Rightarrow \frac{Q_2}{Q_1} = -\frac{T_2}{T_1}$$

$$T_1 \ln(V_2/V_1) = -T_1 \ln(V_1/V_2)$$



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

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

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

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

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

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

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

1. THE REVERSE CARNOT CYCLE_ with LV substance

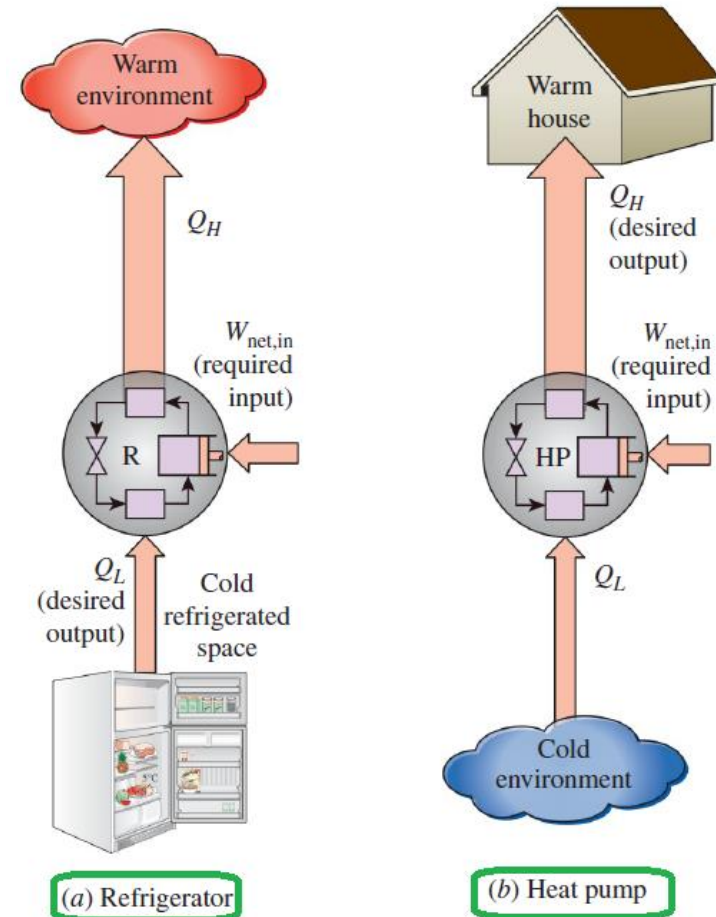
$$COP = \beta_R = \frac{|Q_L|}{|W|} = \frac{|Q_L|}{|Q_H| - |Q_L|} = \frac{1}{\frac{|Q_H|}{|Q_L|} - 1}$$

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

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

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

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



Notice that both COPs increase as the difference between the two temperatures decreases, that is, as T_L rises or T_H falls.

EXAMPLE 1

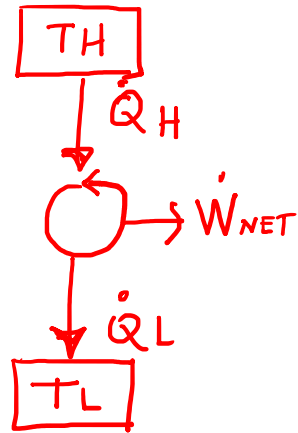
A company is selling thermic machines that operates between 99.85 °C (cold reservoir) and 199.85 °C (hot reservoir) with the characteristics shown in the table below. Verify if they are possible or not and justify each answer mentioning which thermodynamic statement violates.

Se debe inferir si son entrada o salida para cada equipo

Type / (kW)	$ Q_H $	$ Q_L $	$ W $
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

CICLO DE POTENCIA

Masa de control;



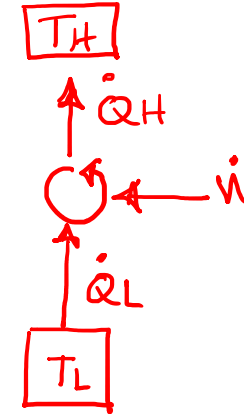
$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

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

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

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

CICLO DE REFRIGERACION { - REFRIGERACION
Masa de control - BOMBA DE CALOR



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

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

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

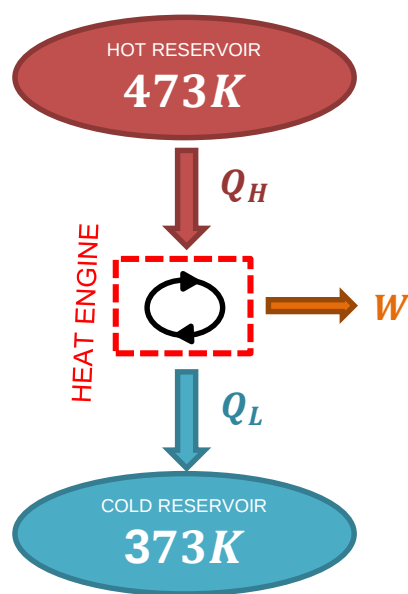
FIRST LAW: $|W| = |Q_H| - |Q_L|$

Type (kW)	$ Q_H $	$ Q_L $	$ W $	Meets the 1st law?	$ W = Q_H - Q_L $
Heat pump	100	76	24	YES	24
<u>Heat engine</u>	<u>100</u>	<u>16</u>	<u>74</u>	<u>NO</u>	<u>84</u>
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

SECOND LAW FOR HEAT ENGINES:

Efficiency of a Heat Engine:

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



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

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

$$\eta_{rev} = 0.211$$

$$\eta \leq \eta_{rev}$$

2nd law for heat engines

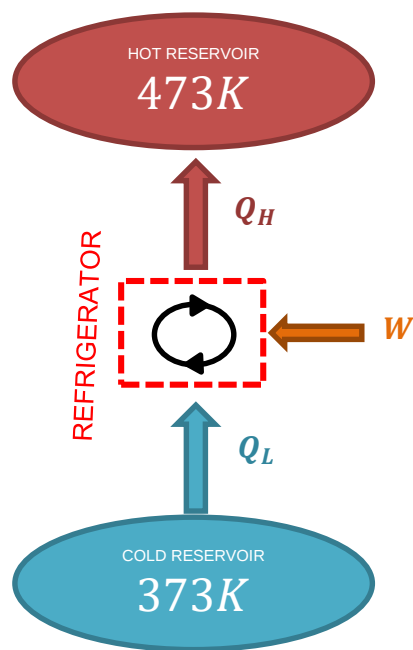
$$\eta \leq 0.211$$

Type / (kW)	$ Q_H $	$ Q_L $	$ W $	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		

SECOND LAW FOR REFRIGERATORS:

COP of a refrigerator:

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



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

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

$$COP_R^{rev} = 3.73$$

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

2nd law for
refrigerators

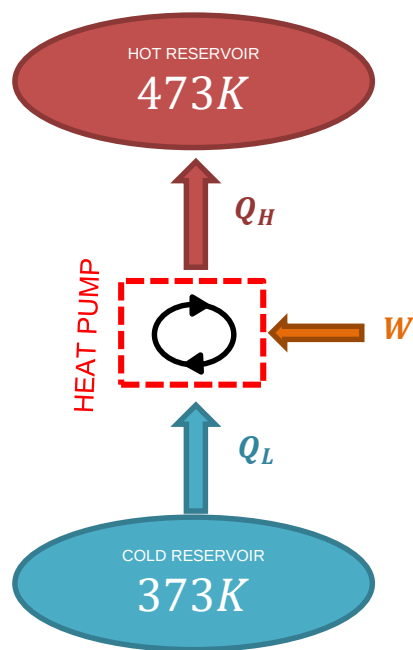
$$COP_R \leq 3.73$$

Type / (kW)	$ Q_H $	$ Q_L $	$ W $	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					
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

$$COP_{HP} \leq 4.73$$

Type / (kW)	$ Q_H $	$ Q_L $	$ W $	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

Efficiency of a Heat Engine:

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

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

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

COP of a refrigerator:

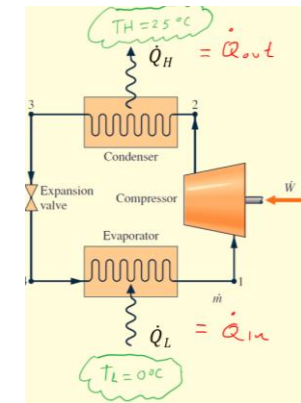
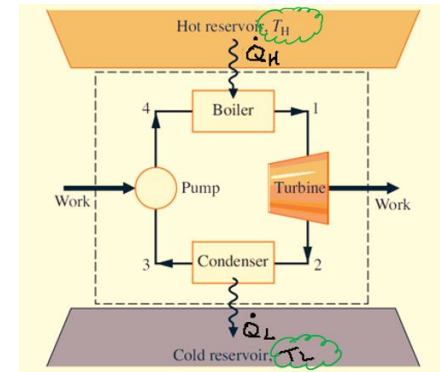
$$COP_R = \beta_R = \frac{|Q_L|}{|W|} = \frac{|Q_L|}{|Q_H| - |Q_L|}$$

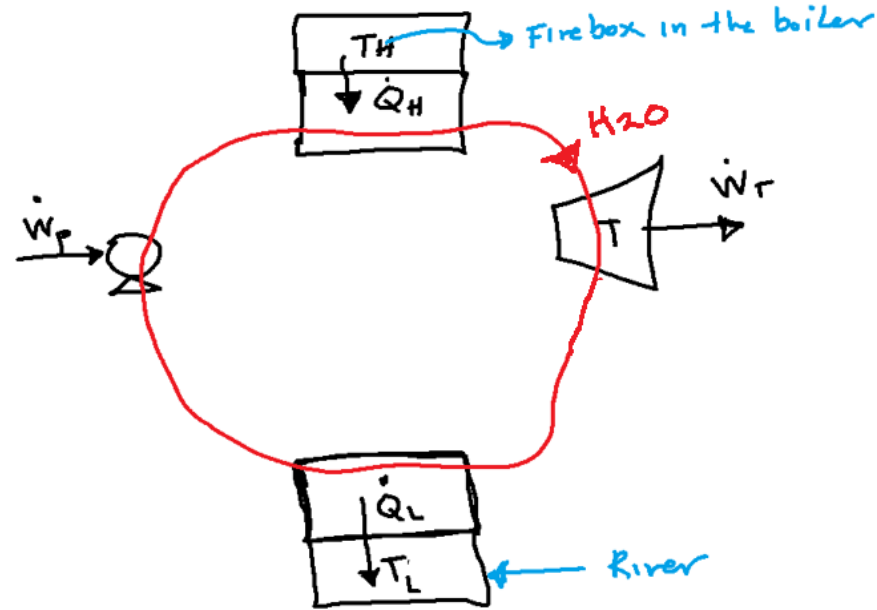
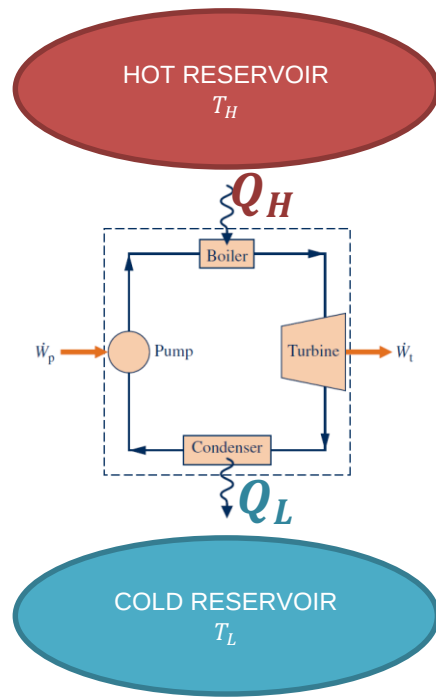
$$COP_R^{ideal} = \frac{|T_L|}{|T_H| - |T_L|}$$

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:

A diagram showing a rectangular box divided horizontally. The bottom half is labeled T_L and contains a red arrow pointing down labeled $\dot{Q}_L$. Two arrows point towards the box from the left, labeled T_{L1} and T_{L2} . Below the box is the equation:

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

A diagram showing a rectangular box divided horizontally. The top half is labeled T_H and contains a red arrow pointing down labeled $\dot{Q}_H$. Two arrows point away from the box to the right, labeled T_{H1} and T_{H2} . Below the box is the equation:

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

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:

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

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:

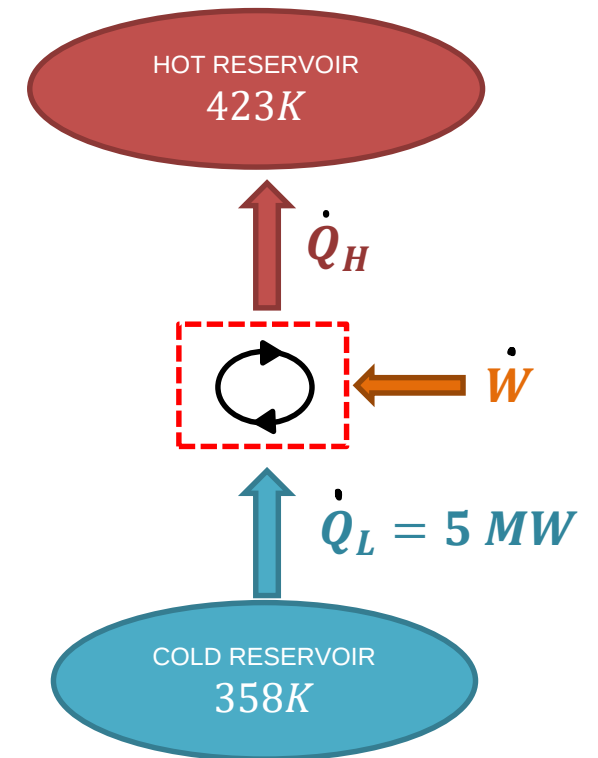
$$|\dot{W}| = ? \quad [MW]$$

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

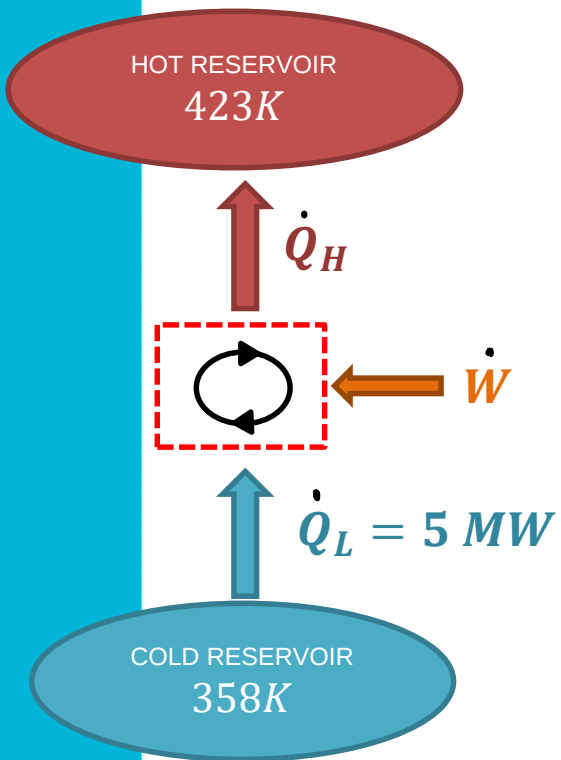
$$T_L = 358 \text{ K}$$

¿cuál tendría que ser la temperatura del depósito caliente?

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



EXERCISE 2



$$\begin{aligned} \uparrow \dot{Q}_H \\ \uparrow \dot{Q}_L \quad \downarrow \dot{W} \\ \frac{dE}{dt} = \dot{Q} - \dot{W} \\ 0 = \dot{Q}_H + \dot{Q}_L - \dot{W} \\ <0 >0 <0 \\ 0 = -|\dot{Q}_H| + |\dot{Q}_L| + |\dot{W}| \\ |\dot{Q}_H| = |\dot{Q}_L| + |\dot{W}| \end{aligned}$$

a) The power required is:

$$\begin{aligned} \text{COP}_{\text{HP}} = \frac{|Q_H|}{|W|} \rightarrow 2.5 = \frac{|Q_L| + |W|}{|W|} \\ 2.5 = \frac{5 + |W|}{|W|} \end{aligned}$$

$$|W| = 3.333 \text{ MW}$$

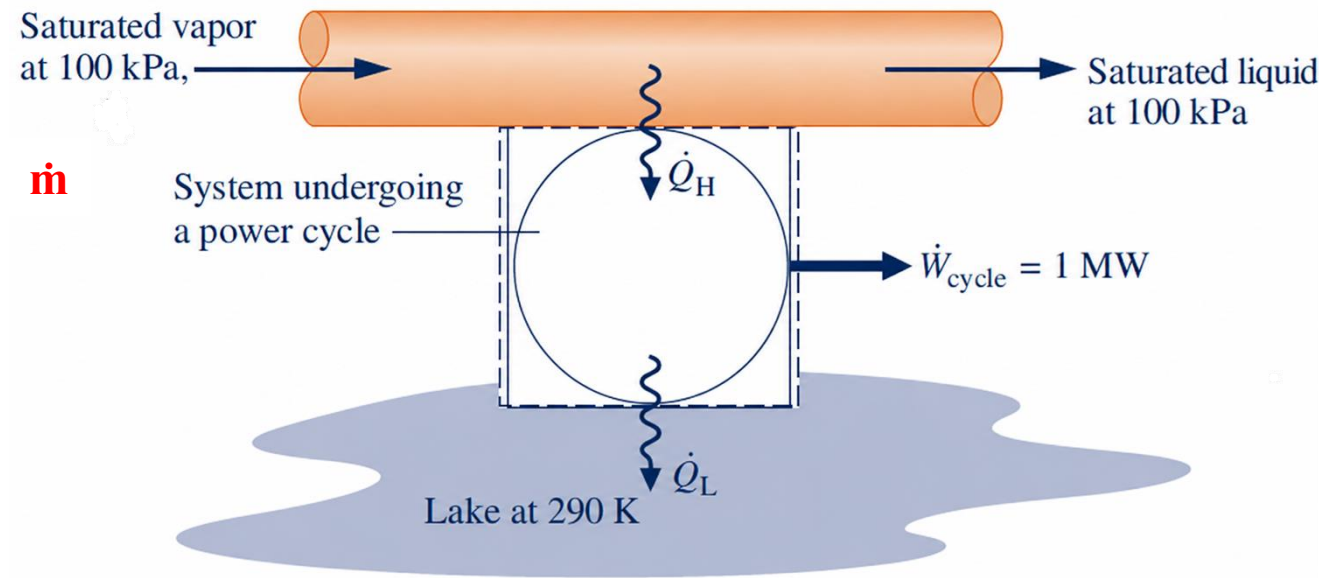
b) The Carnot temperature:

$$\text{COP}_{\text{HP}} = \frac{T_H}{T_H - T_L} \rightarrow 2.5 = \frac{T_H}{T_H - 358}$$

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

EXERCISE 6.2

As shown in the figure shown bellow, a system undergoing a power cycle develops a net power output of 1 MW while receiving energy by heat transfer from steam condensing from saturated vapor to saturated liquid at a pressure of 100 kPa. Energy is discharged from the cycle by heat transfer to a nearby lake at 17°C. These are the only significant heat transfers. Kinetic and potential energy effects can be ignored. For operation at steady state, determine the minimum theoretical steam mass flow rate ($\dot{m}$), in kg/s, required by any such cycle.



As the system undergoes a cyclic process to produce power and the heat transferred from the hot reservoir is produced by steam condensation, the minimum amount of heat required happens when the thermal efficiency is the maximum possible. In other words, when the power efficiency is equal to the Carnot efficiency for power cycles.

$$\text{maximum} \leftarrow \eta = \frac{\dot{W}}{\dot{Q}_H} \rightarrow \begin{matrix} \text{fixed} \\ \text{minimum} \end{matrix}$$

The maximum efficiency is:

$$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{290}{99.63 + 273.15}$$

$$\eta = 0.2221$$

TABLE A-3

Pressure Conversions:
1 bar = 0.1 MPa
= 10² kPa

Properties of Saturated Water (Liquid–Vapor): Pressure Table

Press. bar	Temp. °C	Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg		
		Sat. Liquid <i>v_f</i> × 10 ³	Sat. Vapor <i>v_g</i>	Sat. Liquid <i>u_f</i>	Sat. Vapor <i>u_g</i>	Sat. Liquid <i>h_f</i>	Evap. <i>h_{fg}</i>	Sat. Vapor <i>h_g</i>
1.00	99.63	1.0432	1.694	417.36	2506.1	417.46	2258.0	2675.5

TABLE A-3

Properties of Saturated Water (Liquid–Vapor): Pressure Table

Pressure Conversions:
1 bar = 0.1 MPa
= 10² kPa

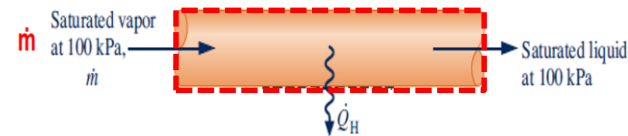
Press. bar	Temp. °C	Specific Volume m ³ /kg		Internal Energy kJ/kg		Enthalpy kJ/kg		
		Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g
1.00	99.63	1.0432	1.694	417.36	2506.1	417.46	2258.0	2675.5

The efficiency is also expressed as:

$$\eta = \frac{|\dot{W}_{cycle}|}{|\dot{Q}_H|} = 0.2221$$

$$\eta = \frac{|1 \text{ MW}|}{|\dot{Q}_H|} = 0.2221$$

$$|\dot{Q}_H| = 4.50247 \text{ MW} = 4502.5 \text{ kW}$$



$$\frac{d\phi}{dt} = \dot{m} (h_1 - h_2) + \dot{Q}_H - \dot{W}$$

$$\dot{Q}_H = \dot{m} (h_2 - h_1)$$

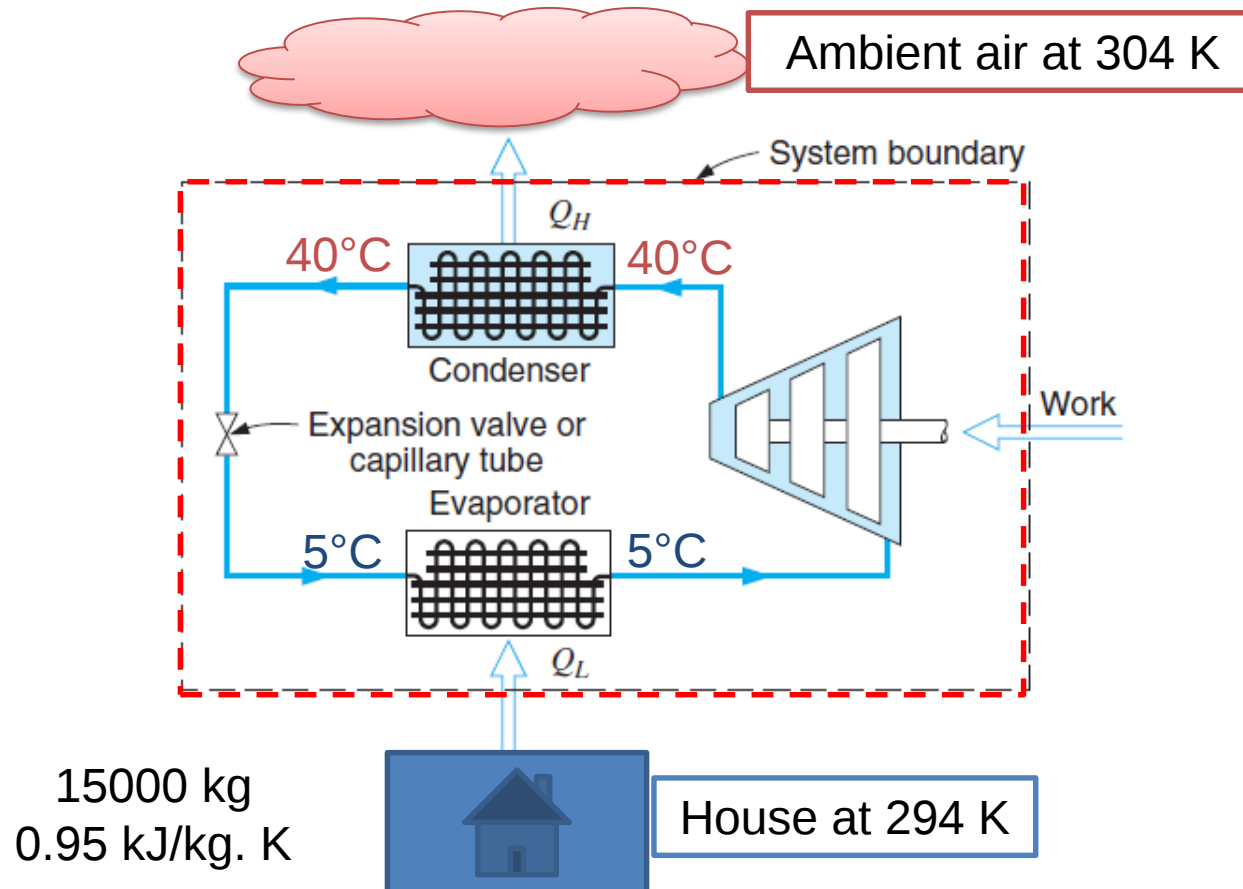
$\rightarrow 2675.5 \frac{\text{kJ}}{\text{kg}}$
 $\leftarrow 417.46 \frac{\text{kJ}}{\text{kg}}$

- 4502.5 kW

$$\dot{m}_V = \frac{\dot{Q}_H}{h_f - h_g} = \frac{-4502.5 \text{ kW}}{-2258.04 \text{ kJ/kg}} = 1.9940 \text{ kg/s}$$

EXERCISE 8.2

An air conditioner on a hot summer day removes 8 kW of energy from a house at 294K and pushes energy to the outside, which is at 304K. The house has a mass of 15 000 kg with an average specific heat of 0.95 kJ/kg. K. In order to do this, the cold side of the air conditioner is at 5°C and the hot side is at 40°C. The air conditioner (refrigerator) has a COP that is 60% that of a corresponding Carnot refrigerator. Find the actual COP of the air conditioner and the power required to run it.



As there is 15000kg of air inside the house, this space can be taken as the cold reservoir because its temperature shouldn't change while the heat is being removed (you can verify it!).

The COP for a Carnot Refrigerator that Works between 294 K and 304 K:

$$\beta_{carnot} = \frac{T_L}{T_H - T_L} = \frac{(294)}{(304) - (294)}$$

$$\beta_{carnot} = 29.4$$

The actual COP for the refrigerator is:

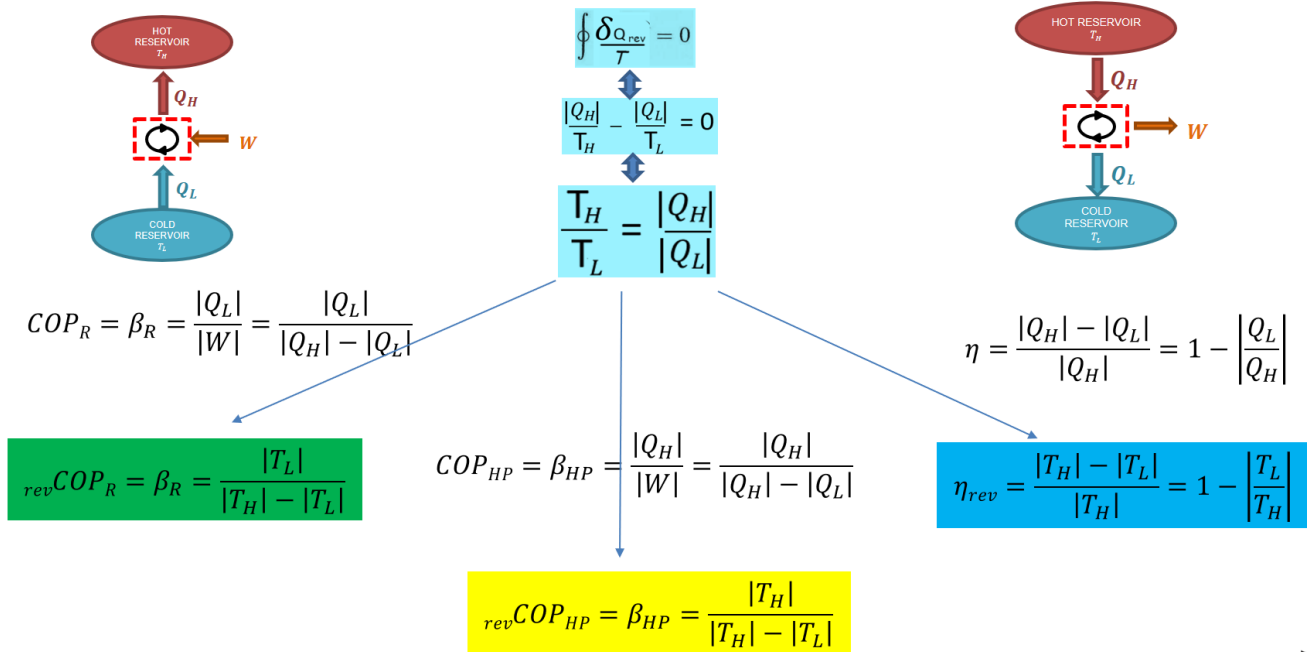
$$\beta = 60\% \beta_{carnot} = 17.64$$

The power required is:

$$\beta = \frac{|Q_L|}{|W|} \rightarrow |W| = \frac{|Q_L|}{\beta}$$

$$|W| = \frac{8 \text{ kW}}{17.64} = 0.4535 \text{ kW}$$

The ideal cycle (T) vs real cycle (Q)

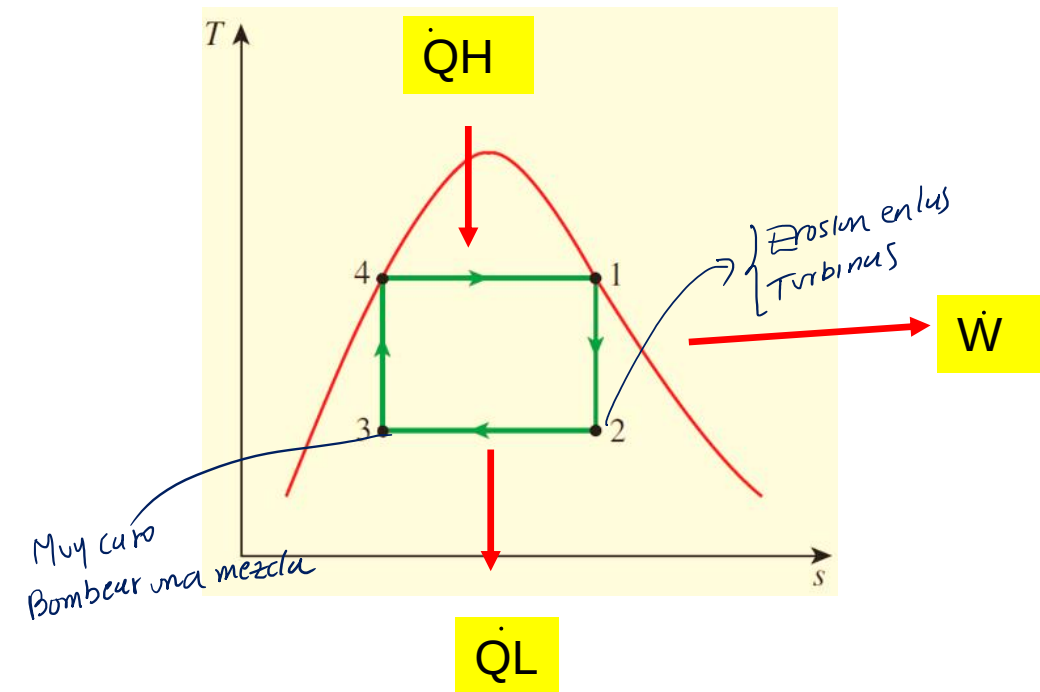
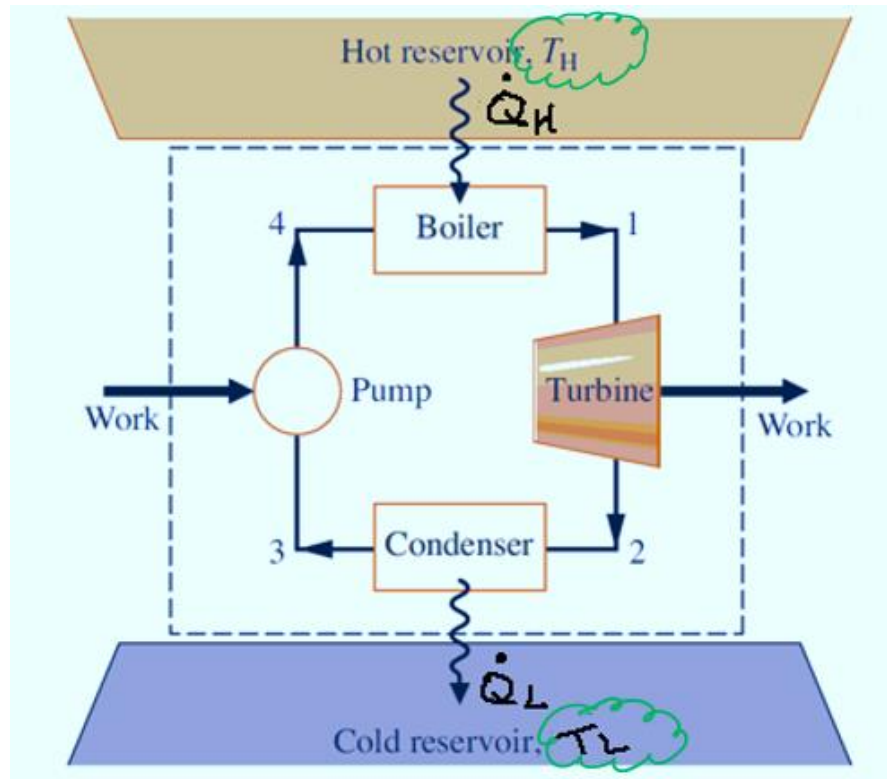


The Carnot cycle, allow us a quantitative approximation for the second law,

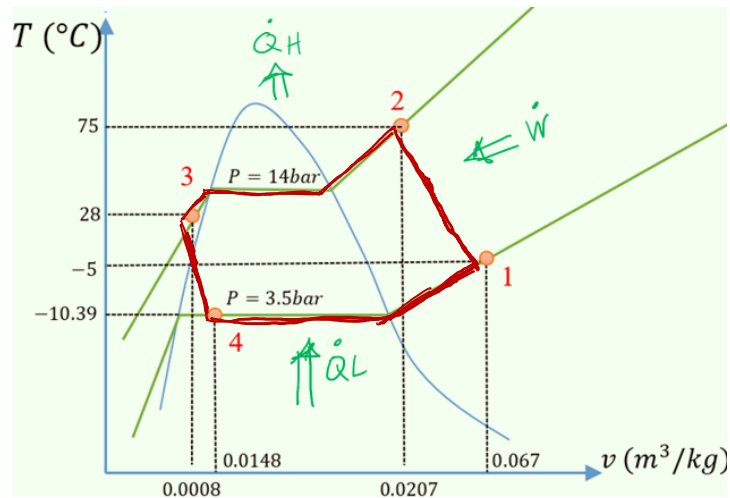
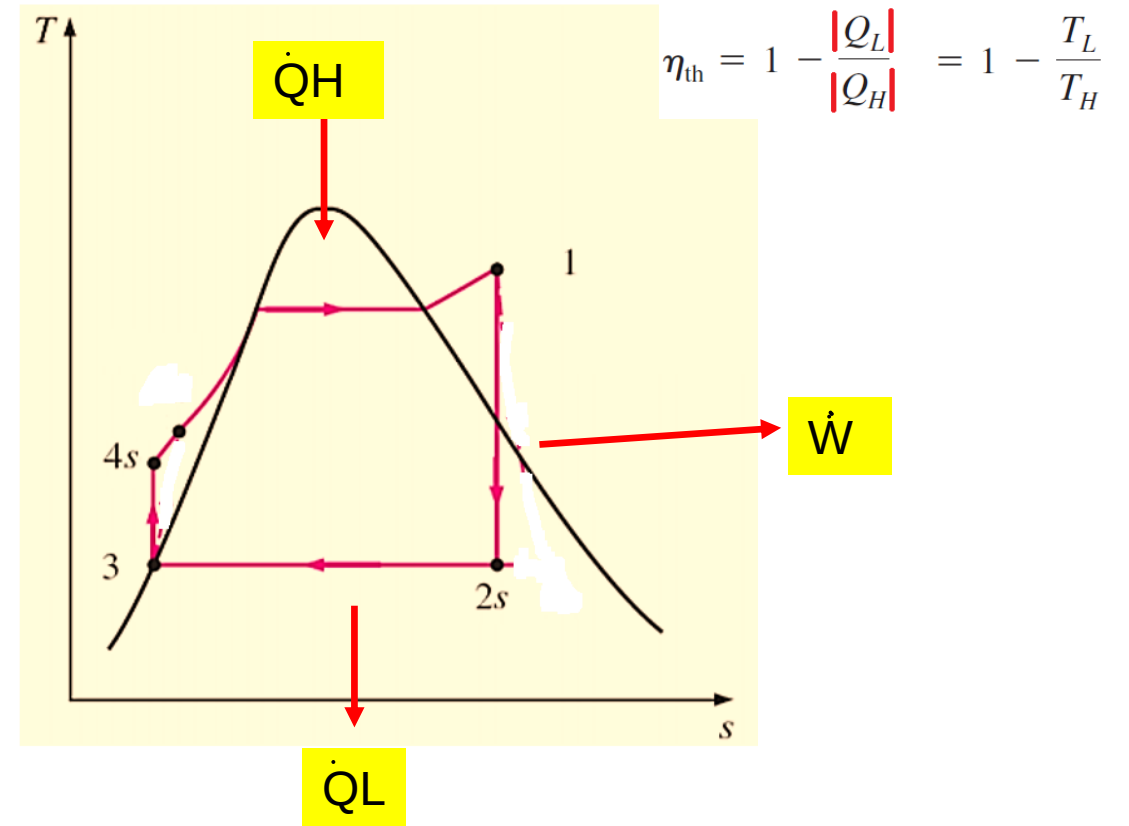
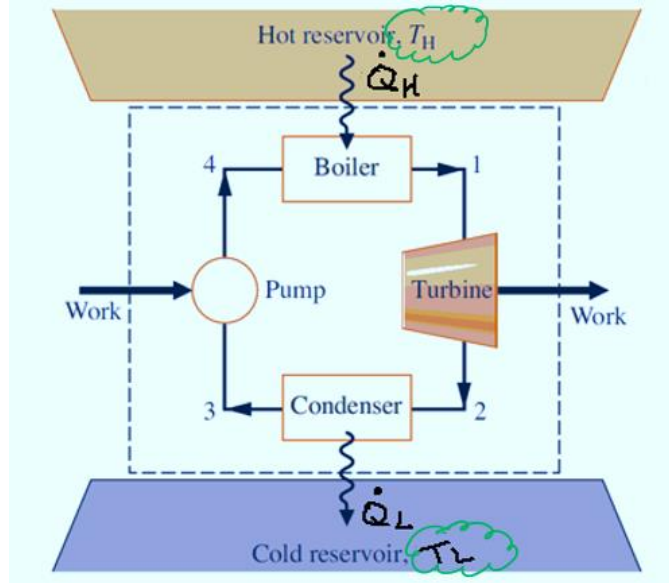
Two important things about Carnot cycles:

1. It can also operate for pure substance, either for a heat engine or for a refrigerator.
2. There are other ideal cycles more applicable in practical conditions. For heat engine we have the **Brayton** cycles (ideal gas) and the **Rankine** cycle (pure substance) and for the refrigeration cycle we have the **vapor compression cycle**.

THE SIMPLE IDEAL CARNOT CYCLE_ Heat Engine with LV substance



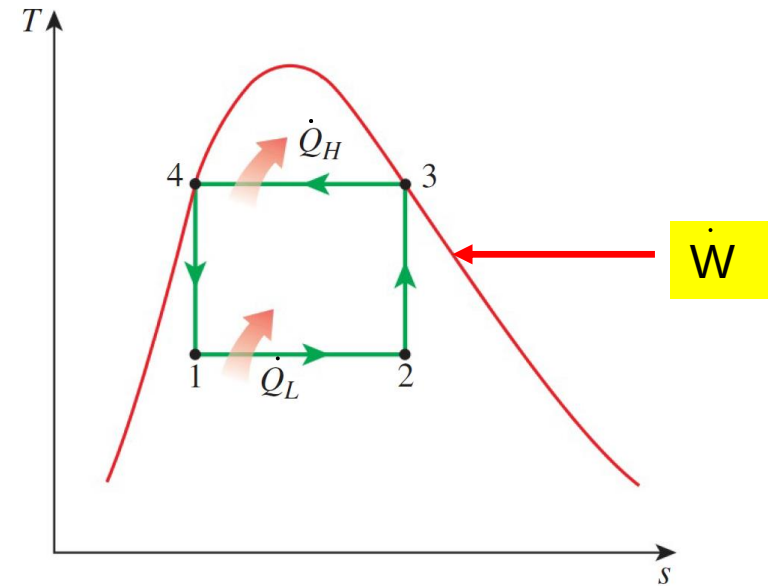
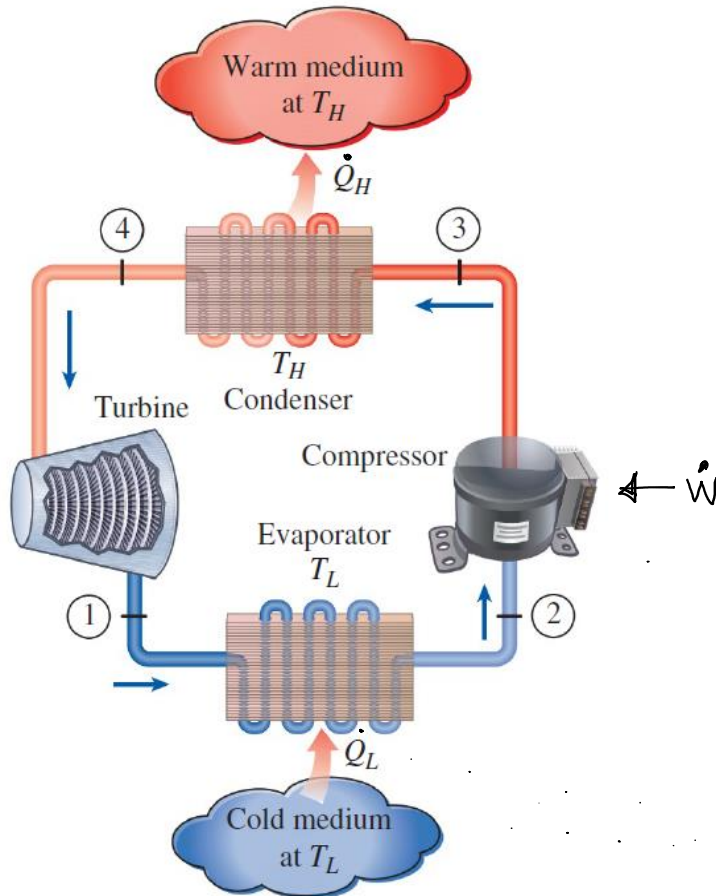
THE SIMPLE IDEAL RANKINE CYCLE_ Heat Engine with LV substance



ppt semana 7

1.

THE IDEAL CARNOT REFRIGERATION CYCLE

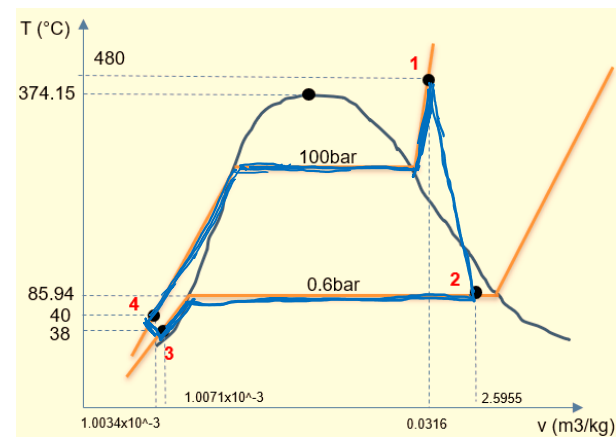
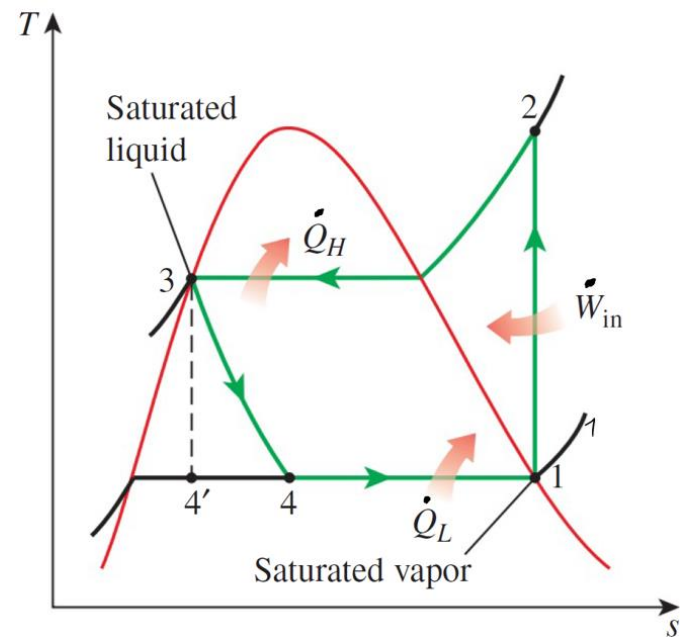
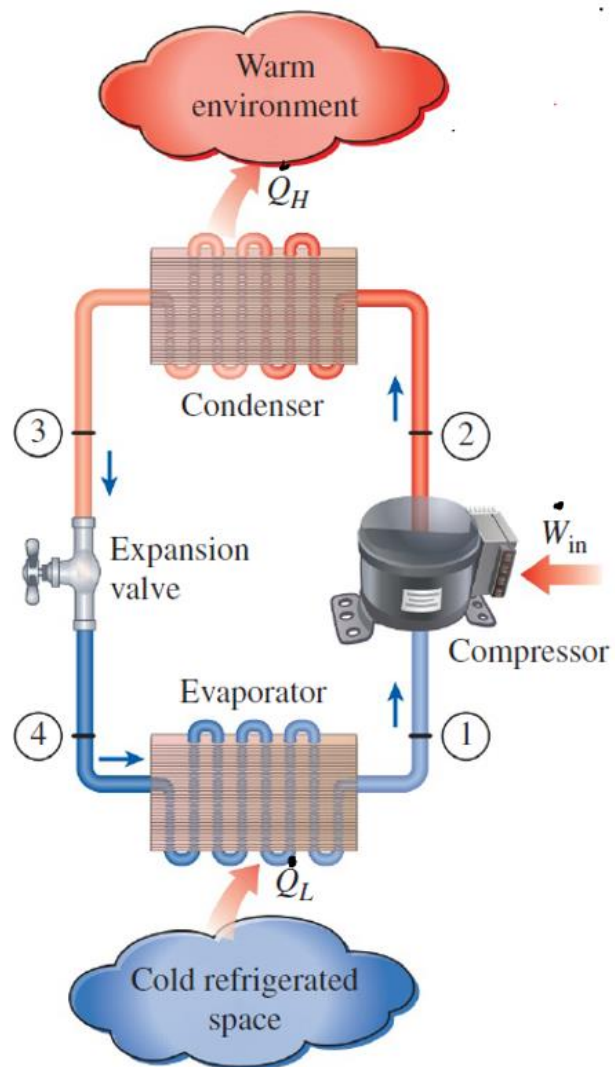


PRACTICAL PROBLEMS:

- *Process 2-3 involves the compression of a liquid-vapor mixture, which requires a compressor that will handle two phases(DAMAGE).
- *Process 4-1 involves the expansion of high-moisture-content refrigerant in a turbine(INEFFICIENT).

1.

THE IDEAL VAPOR-COMPRESSION REFRIGERATION CYCLE



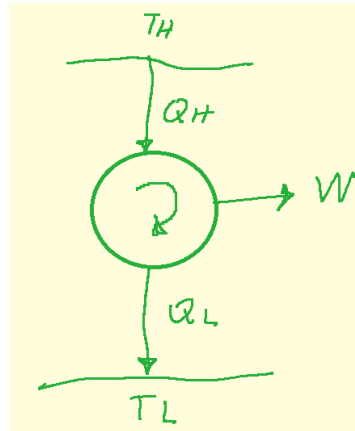
ppt semana 7

Aspects of the Second Law

1. Predicting the direction of processes [*possible or not...*].
2. Evaluating quantitatively the factors that preclude the attainment of the best theoretical performance level [Friction, finite difference of T ...]
3. Determining the best theoretical performance of cycles, engines, and other devices [*COP or η .*].

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)



The first approach to understanding points 1, 2, 3, and 4 is summarized in the Clausius and Kelvin-Planck postulates.

The entropy balance will allow us to address the 4 aspects of the second law quantitatively.

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

Mathematical statement:

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



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

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

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

For reversible $\dot{Q}_L$ is minimum $\Rightarrow \dot{W}_{NET}$ Maximo
 $\dot{Q}_{rev}$ Maximo

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

The Inequality of Clausius

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

Thanks!

