Thermodynamic

2026-1

NEDHER SÁNCHEZ RAMÍREZ

NAUDY LOPEZ

# Work-Heat-First Law_$S_6$ _1_ Mass control

## 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.

## Horas de asesoría 2026-1

| Hora | Lunes | Martes | Miércoles | Jueves | Viernes | Sábado | Hora |
|---|---|---|---|---|---|---|---|
| 7AM - 8AM | | Clases | | Clases | | | 7AM-8AM |
| 8AM - 9AM | | Clases | | Clases | | | 8AM - 9AM |
| 9AM - 10AM | | Clases | Clases | | | | 9AM - 10AM |
| 10AM - 11AM | | Clases | Clases | | | | 10AM - 11AM |
| 11AM - 12PM | | | Clases | | | | 11AM-12PM |
| 12PM - 1PM | | | Clases | | | | 12PM-1PM |
| 1PM - 2PM | | | Clases | | | | 1PM - 2PM |
| 2PM - 3PM | | | Clases | CT: https://utec.zoom.us/j/97371427800 | | | 2PM - 3PM |
| 3PM - 4PM | Clases | | | | | FR: https://utec.zoom.us/j/95953412067 | 3PM - 4PM |
| 4PM - 5PM | Clases | | | | | | 4PM - 5PM |
| 5PM - 6PM | Clases | Clases | Clases | | | | 5PM - 6PM |
| 6PM - 7PM | Clases | Clases | Clases | | | | 6PM - 7PM |
| 7PM - 8PM | | | | | | | 7PM - 8PM |
| 8PM - 9PM | ASESORÍA DE DUDAS: https://utec.zoom.us/j/97136492520 | JG: https://utec.zoom.us/j/92301579107 | | RV: https://utec.zoom.us/j/92982722393 | | | 8PM - 9PM |
| 9PM - 10PM | | | | | | | 9PM - 10PM |

| | | |
|---|---|---|
| RV: Rosario Vidal | Todas las sesiones serán grabadas. | |
| CT: Cristian Tobias | *Varia según disponibilidad | |
| FR: Franklin Rosas | | |
| JG: Jose Gamero | | |

# 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 1:** Todos los temas vistos hasta la semana 6.
**EXAMEN 2:** Todos los temas vistos hasta la semana 15

# Thermodynamics _ Evaluation

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

**EVALUACIÓN CONTINUA (C) :**

La evaluación continua vale un 50% de la nota final

-5 % corresponde a **tareas virtuales ..**Son de corrección automática

-10 % corresponde a **tareas individulales** (ejercicios que los alumnos hacen y suben a la plataforma gradescope) …. ..Ver rúbrica

-17 % corresponde a una **tarea grupal** (proyecto)…..Ver rúbrica

-18% restante corresponde **actividades en aula** (quizes de 20 min aprox)..Ver rúbrica

# 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<br>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.

# Thermodynamics _ Evaluation

**EVALUACIÓN CONTINUA (C) :**

| COMPONENTE | % |
|---|---|
| C | 50 |

**25 %**
- **3 actividades en aula → 9 %**
- **2 tareas individuales → 5 %**
- **½ tareas virtuales → 2.5 %**
- **1ra entrega tarea grupal → 8.5 %**

**25 %**
- **3 actividades en aula → 9 %**
- **2 tareas individuales → 5 %**
- **½ tareas virtuales → 2.5 %**
- **2da entrega tarea grupal → 8.5 %**

Estos dos bloques los redondeamos hacia arriba

√ PARCIALES Y FINALES siguen las reglas normales del reglamento

# OBJECTIVE:

1. **Session 9-10-11: Describe the concepts of energy, heat and work and relate them to the principle of conservation of energy (first law of thermodynamics): Enthalpy, Electric work…..Cycles (AULA).**

1ra ley → Masa de control (semanas 5-6)

$$\Delta E = Q_{NET} - W_{NET} \quad (*)$$

($\Delta E$: 1), $Q_{NET}$: 2), $W_{NET}$: 3))

① Visto en semanas 1-4 para 4s tipos de sustancia

② Despejamos de la ecuación (*)

③ Despejamos o Lo hallamos analítico/

- $W_c = IVt$ → Hoy (AUDITORIO 6-1)
- $W_{PV} = \int P_{(v)}\, dV$

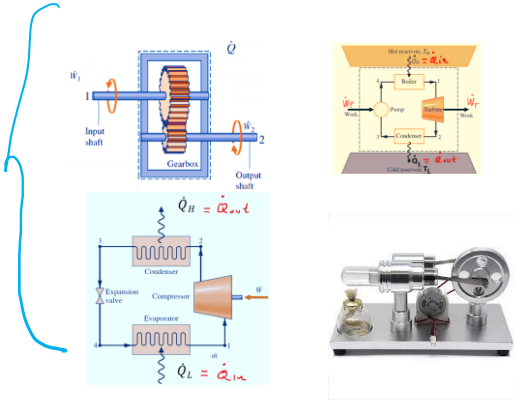
↳ Ya Lo vimos
- Resorte lineal
- $P = cte$
- $PV = cte$
- $PV^n = cte$

* Recordar que existen 2 formas de hacer Los balances (AULA 5-2)

Para procesos que ocurren continuamente.

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

↳ La vimos el Lunes pasado
La aplicamos en AULA 6-2

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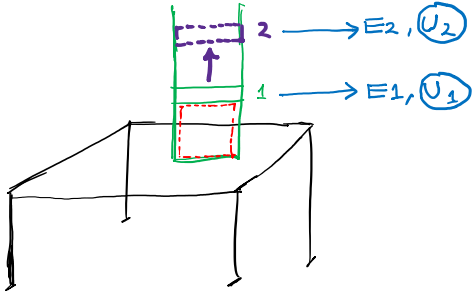
# Energy Accounting: Energy Balance for Closed Systems

[ *change* in the amount of energy contained within a system during some time interval ] = [ *net* amount of energy transferred *in* across the system boundary by *heat* transfer during the time interval ] − [ *net* amount of energy transferred *out* across the system boundary by *work* during the time interval ]

$\Delta E$

$$E_2 - E_1 = Q - W$$

$$\Delta KE + \Delta PE + \Delta U = Q - W$$

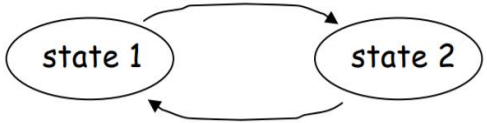


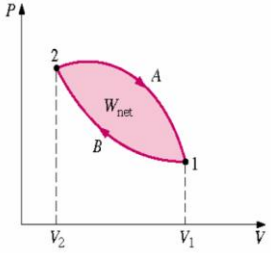
# Work, Heat, and the First Law

**WORK**

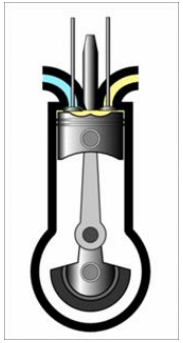
Work (w) is not a function of state.

For a cyclic process, it is possible for $\oint \delta W \neq 0$



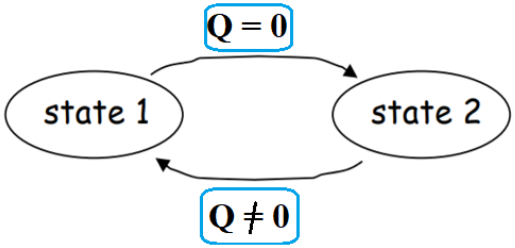




$$\oint \delta W = \oint P dV \neq 0$$



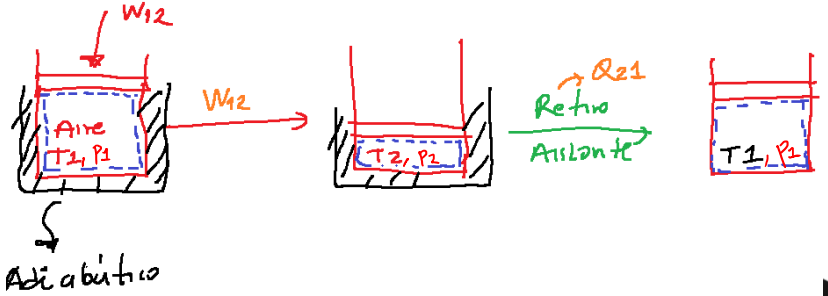
**HEAT**

Heat (**Q**), like $W$, is a function of path. Not a state function




$$\oint \delta Q \neq 0$$

System: air inside

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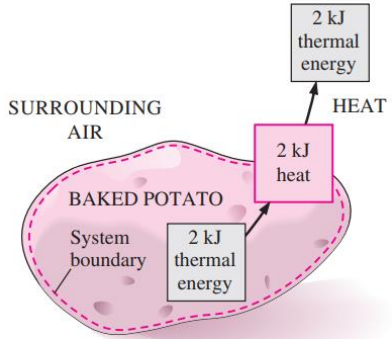
# HOW CAN A SYSTEM EXCHANGE ITS ENERGY?

## a) Heat

Work too!

Heat is energy in transition. It is recognized only as it crosses the boundary of a system:




$$\frac{dE}{dt} = \dot{Q} - \dot{W} \quad [kW]$$

$$\Delta U = Q - W \quad [kJ]$$

$$\Delta u = q - w \quad \left[\frac{kJ}{kg}\right]$$

Heat transfer *per unit mass* of a system is denoted $\boldsymbol{q}$ and is determined from:

$$q = \frac{Q}{m} \qquad (kJ/kg)$$

$$\dot{Q} \ (kJ/s) \ \text{or} \ kW$$

$$Q = \int_{t_1}^{t_2} \dot{Q}\, dt \ \ kJ$$

$w \rightsquigarrow \frac{kJ}{kg}$

$\dot{W} \rightsquigarrow \frac{kJ}{s}$ or kW

$W \rightsquigarrow kJ$

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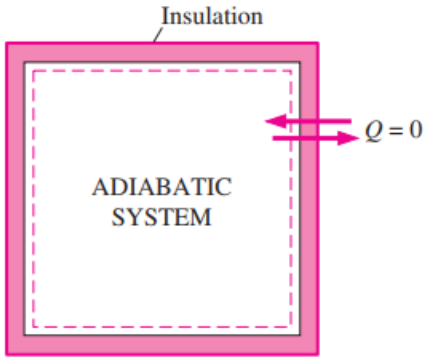
# HOW CAN A SYSTEM EXCHANGE ITS ENERGY?

## a) Heat_ adiabatic

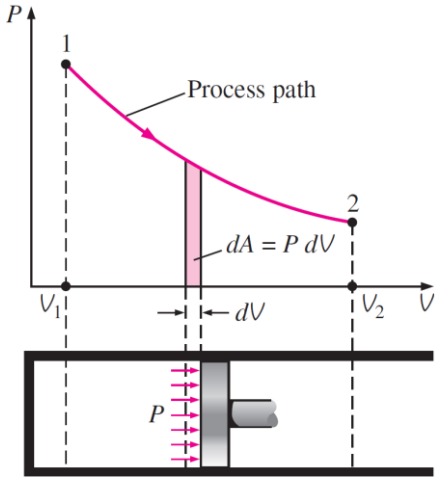



During an adiabatic process, a system exchanges no heat with its surroundings.

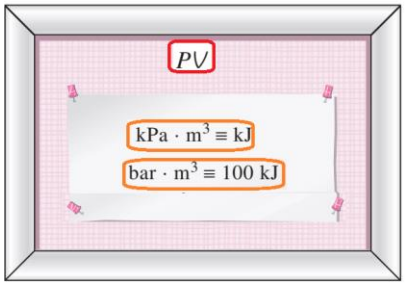
# The Moving Boundary Work ( PV -Work)

**In Mechanics:** $W = \int_1^2 \delta W = \int_1^2 \vec{F} \cdot d\vec{x}$

**Moving Boundary Work:** $\delta W = PAdx \rightarrow \delta W = PdV \rightarrow W = \int_1^2 PdV = W_{boundary} = W_b = W_{pv}$




**If the process is quasistatic (or reversible), the pressure within the system can be considered uniform at each instant. Therefore, a single pressure value is representative of the system, and the boundary work can be written as above**

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# Which of the following equations FOR WORK can be used for any substance, ideal gas or not?

P = cte

$$W_b = \int_1^2 P\,dV = P_0 \int_1^2 dV = P_0(V_2 - V_1)$$

PV = cte

$$P_1V_1 = P_2V_2 = C$$

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-1}\,dV = PV\ln\left(\frac{V_2}{V_1}\right)$$

↳ UNIVERSAL

**Isothermal Compression of an Ideal Gas**

$$P_1V_1 = P_2V_2 = C = m\bar{R}/M\,T_0$$

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-1}\,dV = m\bar{R}/M\,T_0\ln\left(\frac{V_2}{V_1}\right)$$

↳ GAS IDEAL

$PV^n = cte$

$$C = P_1V_1^n = P_2V_2^n$$

→ UNIVERSAL

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-n}\,dV = C\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{1-n}$$

For an ideal gas ($PV = m\bar{R}/MT$)

$$W_b = \frac{m\bar{R}/M\,(T_2 - T_1)}{1-n}$$

↳ GAS IDEAL

* RESORTE LINEAL

↳ UNIVERSAL

$P = C_1 + C_2V$

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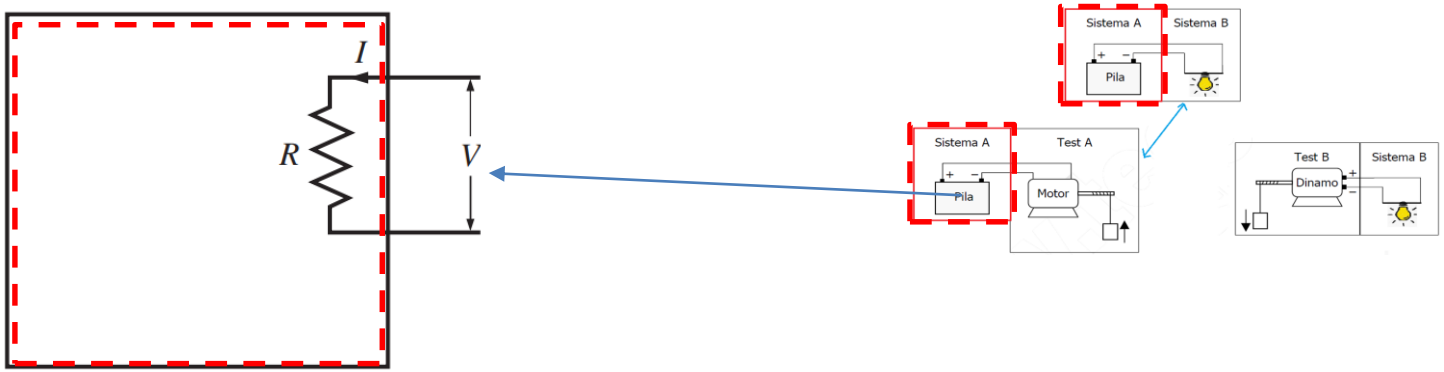
- **DEFINITION: Work -- is done by a system (on its surroundings) if the sole effect on everything external to the system could have been the raising of a weight**




When both **V** and $I$ remain constant during the time interval $\Delta t$

$$|\dot{W}_e| = \mathbf{V}I \quad (\mathrm{W}) \quad (\mathrm{J/s} = \mathrm{W}) \qquad |W_e| = \mathbf{V}I\,\Delta t \quad (\mathrm{J}) \qquad |W_e| = \mathbf{V}I\,\Delta t = (\mathrm{V})(\mathrm{A})(\mathrm{s}) = \mathrm{J}$$

$$|W_e| = (\mathrm{V})(\mathrm{A})(\mathrm{s})\left(\frac{1\ \mathrm{kJ/s}}{1000\ \mathrm{VA}}\right) = \mathrm{kJ}$$

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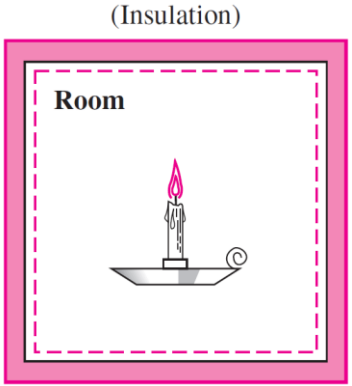
## Burning of a Candle in an Insulated Room

A candle is burning in a well-insulated room. Taking the room (the air plus the candle) as the system, determine **(*a*) if there is any heat transfer during this burning process** and **(*b*) if there is any change in the internal energy of the system.**




***Analysis***

**(*a*)** The interior surfaces of the room form the system boundary, as indicated by the dashed lines in the Fig. Heat is recognized as it crosses the boundaries. Since the room is well insulated, we have an adiabatic system and no heat will pass through the boundaries. Therefore, $Q = 0$ for this process.

**(*b*)** The internal energy involves energies that exist in various forms (sensible, latent, chemical, nuclear). During the process just described, part of the chemical energy is converted to sensible energy. Since there is no increase or decrease in the total internal energy of the system, $\Delta U = 0$ for this process.

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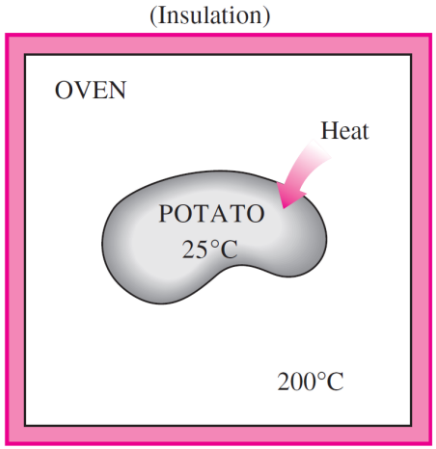
# Heating of a Potato in an Oven

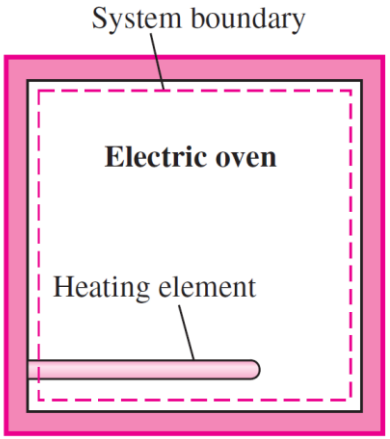
A potato initially at room temperature (25°C) is being baked in an oven that is maintained at 200°C, as shown in the Fig. **Is there any heat transfer during this baking process?**




***Analysis*** This is not a well-defined problem since the system is not specified. Let us assume that we are observing the potato, which will be our system. Then the skin of the potato can be viewed as the system boundary. Part of the energy in the oven will pass through the skin to the potato. Since the driving force for this energy transfer is a temperature difference, this is a heat transfer process.

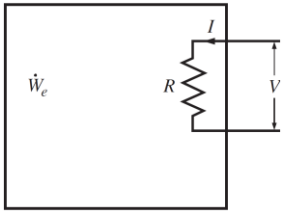
## Heating of an Oven by Work/heat Transfer

A well-insulated electric oven is being heated through its heating element. If the entire oven, including the heating element, is taken to be the system, **determine whether this is a heat or work interaction.**




$$\Delta U = \dot{Q}^{?} - \dot{W}^{?}$$

***Analysis*** For this problem, the interior surfaces of the oven form the system boundary, as shown in the Fig. The energy content of the oven obviously increases during this process, as evidenced by a rise in temperature. This energy transfer to the oven is not caused by a temperature difference between the oven and the surrounding air. Instead, it is caused by *electrons* crossing the system boundary and thus doing work. Therefore, **this is a work interaction.**

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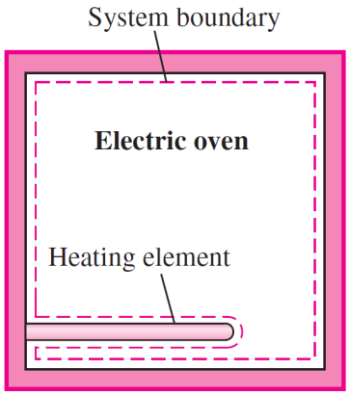
## Heating of an Oven by Work/heat Transfer

If the system is taken as only the air in the oven without the heating element. **Determine whether this is a heat or work interaction.**

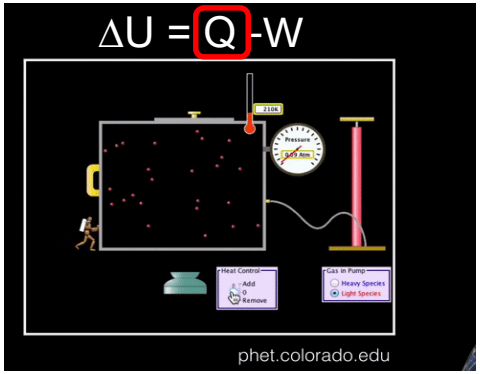



***Analysis*** This time, the system boundary will include the outer surface of the heating element and will not cut through it, as shown in Fig. Therefore, no electrons will be crossing the system boundary at any point. Instead, the energy generated in the interior of the heating element will be transferred to the air around it as a result of the temperature difference between the heating element and the air in the oven. Therefore, this is a heat transfer process.

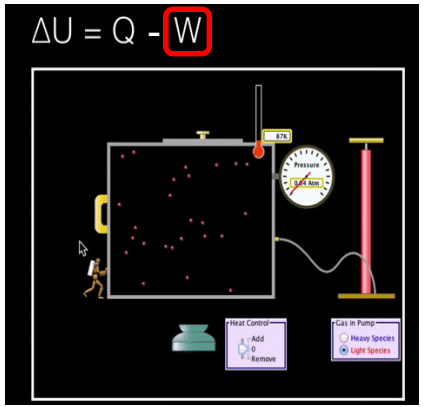
***Discussion*** For both cases, the amount of energy transfer to the air is the same. These two examples show that an energy transfer can be heat or work, depending on how the system is selected.

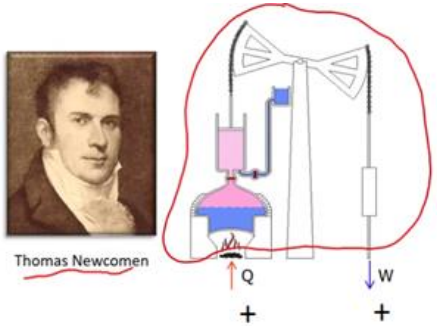
# Work, Heat, and the First Law_ Closed system

Let's assume $\Delta V = 0$




Let's assume adiabatic process





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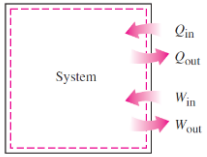
# First law of thermodynamics _Closed system_ Multiple inputs

What happens if we have several inputs of heat and work?

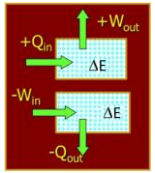
$$(Q_{in} - Q_{out}) + (W_{in} - W_{out}) = \Delta E_{system}$$ or $$Q_{NET} - W_{NET} = \Delta E$$

it is not necessary to assume the convention of signs in the solution, instead know if it is in or out:




Specifying the directions of heat and work.

Assume the convention of signs in the solution




- ***Both need to know the directionality of the W and Q to know if it is in or out or positive or negative.***

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**EXAMPLE 1:** A closed, rigid tank fitted with a fine-wire electric resistor is filled with Refrigerant 22, initially at -10°C, a quality of 80%, and a volume of 0.01 $m^3$. A 12-volt battery provides a 5-amp current to the resistor for 5 minutes. If the final pressure of the refrigerant is 5.5 bar, determine $T_2[^oC]$ and the heat transfer [kJ] from the refrigerant. Assume the process is quasistatic.

*Assumptions 1*:
- ΔKE = ΔPE = 0. Therefore, ΔE = ΔU.

Estado 1 $\{T_1, x_1 \Rightarrow P_1, u_1, v_1, m$

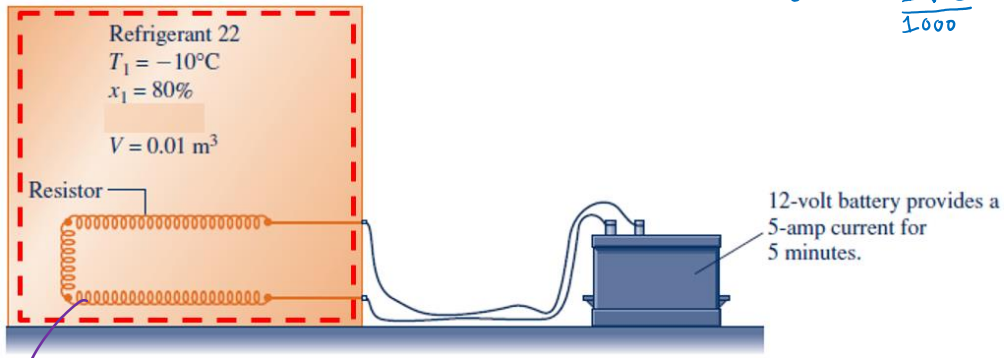
$v_1$

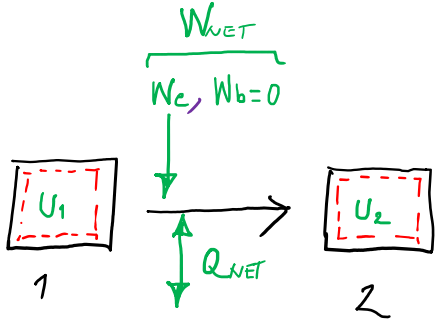
Estado 2 $\{P_2, v_2 = v_1 \Rightarrow u_2, T_2$

$\Delta U = Q_{NET} - (W_b + W_e)$

$m(u_2 - u_1) = Q_{NET} - (W_b + W_e)$

$W_b$: 0 ; $W_e$: $-\frac{IVt}{1000}$




Se infiere que es trabajo electrico pues la resistencia está dentro del sistema, estando afuera sería calor

State 1:

$\boldsymbol{v_1} = 0.7606 \times 10^{-3} + 0.8(0.0652 - 0.7606 \times 10^{-3})$

$\boldsymbol{v_1 = 0.0523\ m^3/kg}$

$\boldsymbol{m} = \frac{0.01}{0.0523} = \boldsymbol{0.1912\ kg}$

$\boldsymbol{u_1} = 33.27 + 0.8(223.02 - 33.27) = \boldsymbol{185.07\ kJ/kg}$

**TABLE A-7**

Properties of Saturated Refrigerant 22 (Liquid–Va

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

| Temp. °C | Press. bar | Specific Volume $m^3/kg$ Sat. Liquid $v_f \times 10^3$ | Specific Volume $m^3/kg$ Sat. Vapor $v_g$ | Internal Energy kJ/kg Sat. Liquid $u_f$ | Internal Energy kJ/kg Sat. Vapor $u_g$ | Sat. Liquid $h_f$ |
|---|---|---|---|---|---|---|
| −10 | 3.5485 | 0.7606 | 0.0652 | 33.27 | 223.02 | 33.5 |

$P_1$

State 2:

$\boldsymbol{v_2} = v_1 = \boldsymbol{0.0523\ m^3/kg}$

$\boldsymbol{P_2 = 5.5 bar}$

**Interpolating….**

$\boldsymbol{u_2 = 254.47\ kJ/kg}$

$\boldsymbol{T_2} = 46.9417\ ^oC$

**TABLE A-8**

Properties of Saturated Refrigerant 22 (Liquid–Vapor): Pressure Table

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

| Press. bar | Temp. °C | Specific Volume $m^3/kg$ Sat. Liquid $v_f \times 10^3$ | Specific Volume $m^3/kg$ 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 $s_g$ | Press. bar |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.50 | 3.08 | 0.7867 | 0.0427 | 48.30 | 227.53 | 48.74 | 202.28 | 251.02 | 0.1903 | 0.9226 | 5.50 |

$0.0523 > 0.0427$

**TABLE A-9**

(*Continued*)

| T °C | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg · K |
|---|---|---|---|---|
| | $p = 5.5$ bar $= 0.55$ MPa ($T_{sat} = 3.08°C$) | | | |
| 45 | 0.05190 | 253.27 | 281.82 | 1.0264 |
| 50 | 0.05293 | 256.36 | 285.47 | 1.0378 |

Energy balance for closed systems, neglecting kinetic and potential energy

$$U_2 - U_1 = Q - W$$

$$m(u_2 - u_1) = Q - W$$

Electric work:
P=VI
W=Pt=VIt

$$|W_e| = VI\,\Delta t = (\mathrm{V})(\mathrm{A})(\mathrm{s}) = \mathrm{J}$$

The **Electric work** is negative because is done on the system

$$0.1912 \times (254.47 - 185.07) = Q - (-VIt)$$

V A S

$$13.27 = Q + \frac{12 \times 5 \times (5 * 60)}{1000}$$

$$Q = -4.7307\ kJ$$

**De salida!!**

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# HOMEWORK

P[Kpa]-v[m3/kg] diagram??

# Exercises 2:

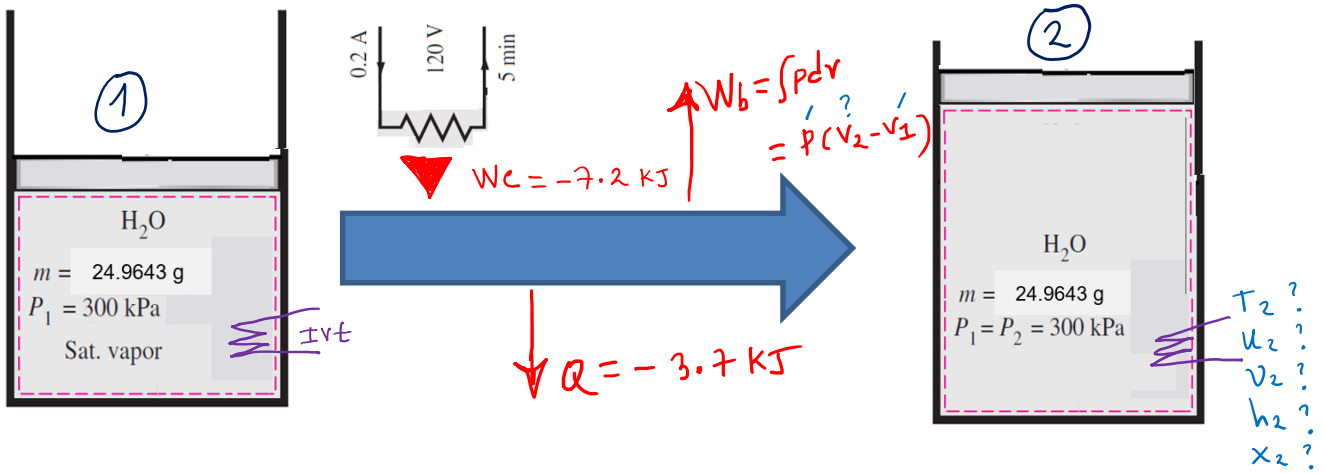
## First Law_Energy Balance_ Closed system

A piston–cylinder device contains 24.9643 g of saturated water vapor that is maintained at a constant pressure of 300 kPa. A resistance heater within the cylinder is turned on and passes a current of 0.2 A for 5 min from a 120-V source. At the same time, a heat loss of 3.7 kJ occurs. (*a*) Show that for a closed system the boundary work $W_b$ and the change in internal energy $U$ in the first-law relation can be combined into one term, $H$, for a constant pressure process. (*b*) **Determine the final temperature of the steam and the p[Kpa]-v[m3/Kg] diagram.** Assume the process is quasistatic.

*Assumptions 1*:

- $\Delta KE = \Delta PE = 0$. Therefore, $\Delta E = \Delta U$.

$$W_e = VI\Delta t = (120\text{V})(0.2\text{A})(300s) \times \frac{1}{1000} = 7.2kJ$$

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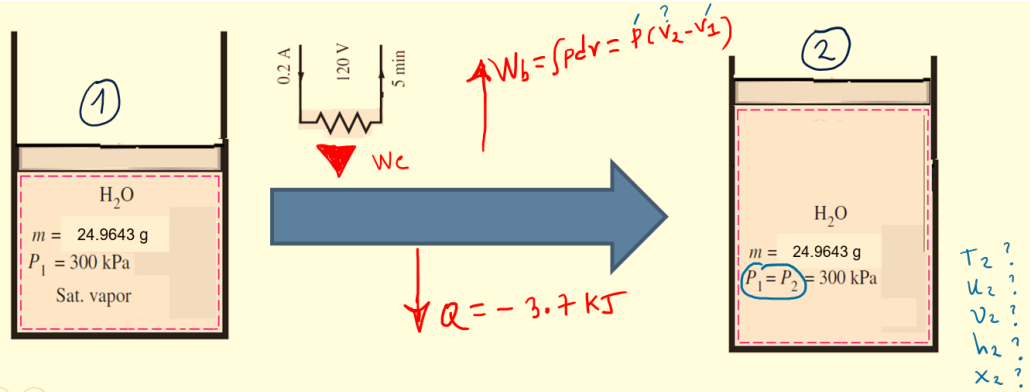
# Exercises 1:




a)

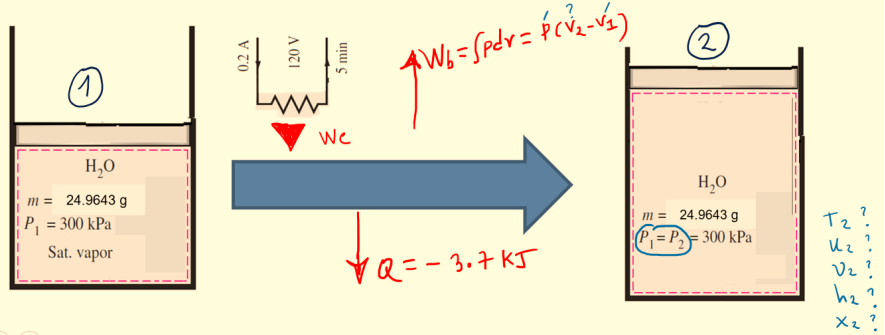
$$Q - W_{NET} = \Delta U$$

$$Q - (W_e + W_b) = U_2 - U_1$$

$$Q - (W_e + W_b) = m(u_2 - u_1)$$

? ?

# Exercises 1: First Law Energy Balance




a)

$$Q - (W_e + W_b) = U_2 - U_1$$

$$\boldsymbol{P = P_1 = P_2}$$

$$Q - W_e - P[V_2 - V_1] = U_2 - U_1 \quad \Leftrightarrow \quad Q - W_e - P_2V_2 + P_1V_1 = U_2 - U_1$$

$$Q - W_e = (U_2 + P_2V_2) - (U_1 + P_1V_1)$$

$$\boldsymbol{Q - W_e = H_2 - H_1}$$

$$\Delta H = Q - W_{\neq PV}$$

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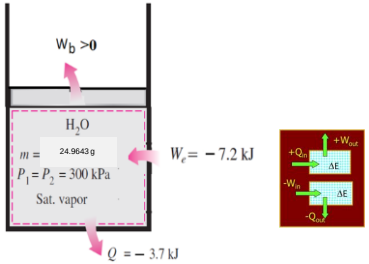
# Exercises 2:

b) State 1, saturated vapor at 300kPa

$h_1 = 2725.3\ kJ/kg$

$\boldsymbol{Q - W_e = H_2 - H_1}$

$Q - W_e = m(h_2 - h_1)$




Q < 0 is going out of the system , $W_e$ < 0 is entering

$-3.7 + 7.2 = 0.0249643(h_2 - 2725.3)$

$h_2 = 2865.5\ kJ/kg$

State 2:

$P_2 = 300kPa$

$h_2 = 2865.5\ kJ/kg$

$\boldsymbol{T_2 = 200°C}$

**TABLE A-3**

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

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

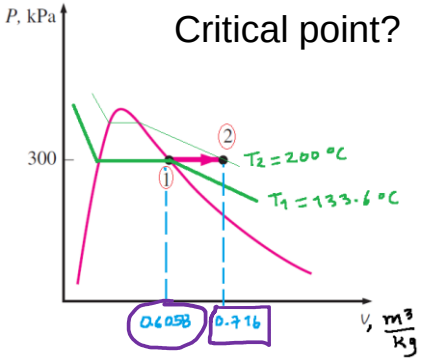
| Press. bar | Temp. °C | Specific Volume $m^3/kg$ Sat. Liquid $v_f \times 10^3$ | Specific Volume $m^3/kg$ Sat. Vapor $v_g$ | Internal Energy kJ/kg Sat. Liquid $u_f$ | Internal Energy kJ/kg Sat. Vapor $u_g$ | Enthalpy kJ/kg Sat. Liquid $h_f$ | Enthalpy kJ/kg Evap. $h_{fg}$ | Enthalpy kJ/kg Sat. Vapor $h_g$ | Entropy kJ/kg · K Sat. Liquid $s_f$ | Entropy kJ/kg · K Sat. Vapor $s_g$ | Press. bar |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.00 | 133.6 | 1.0732 | 0.6058 | 561.15 | 2543.6 | 561.47 | 2163.8 | 2725.3 | 1.6718 | 6.9919 | 3.00 |

**TABLE A-4**

**Properties of Superheated Water Vapor**

| T °C | v $m^3/kg$ | u kJ/kg | h kJ/kg | s kJ/kg · K |
|---|---|---|---|---|
| $p = 3.0$ bar $= 0.30$ MPa ($T_{sat} = 133.55°C$) | | | | |
| 160 | 0.651 | 2587.1 | 2782.3 | 7.1276 |
| 200 | 0.716 | 2650.7 | 2865.5 | 7.3115 |

Critical point?

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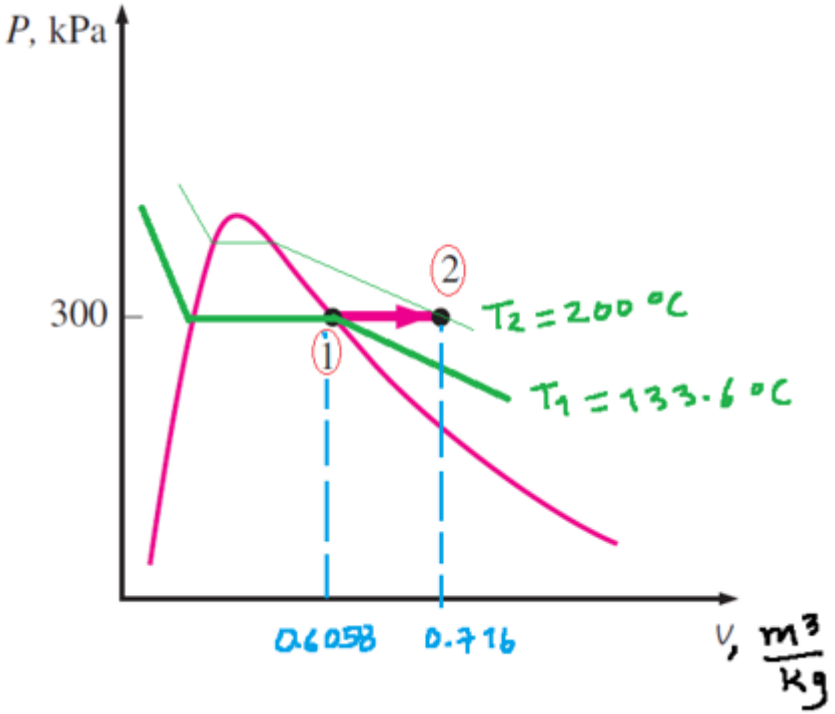
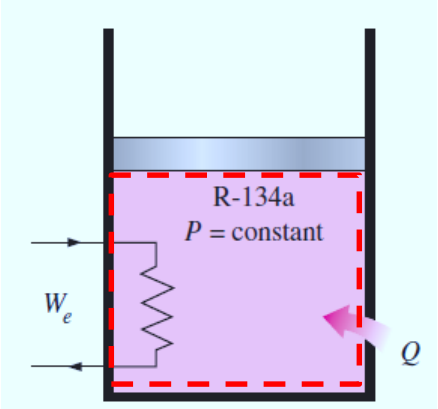
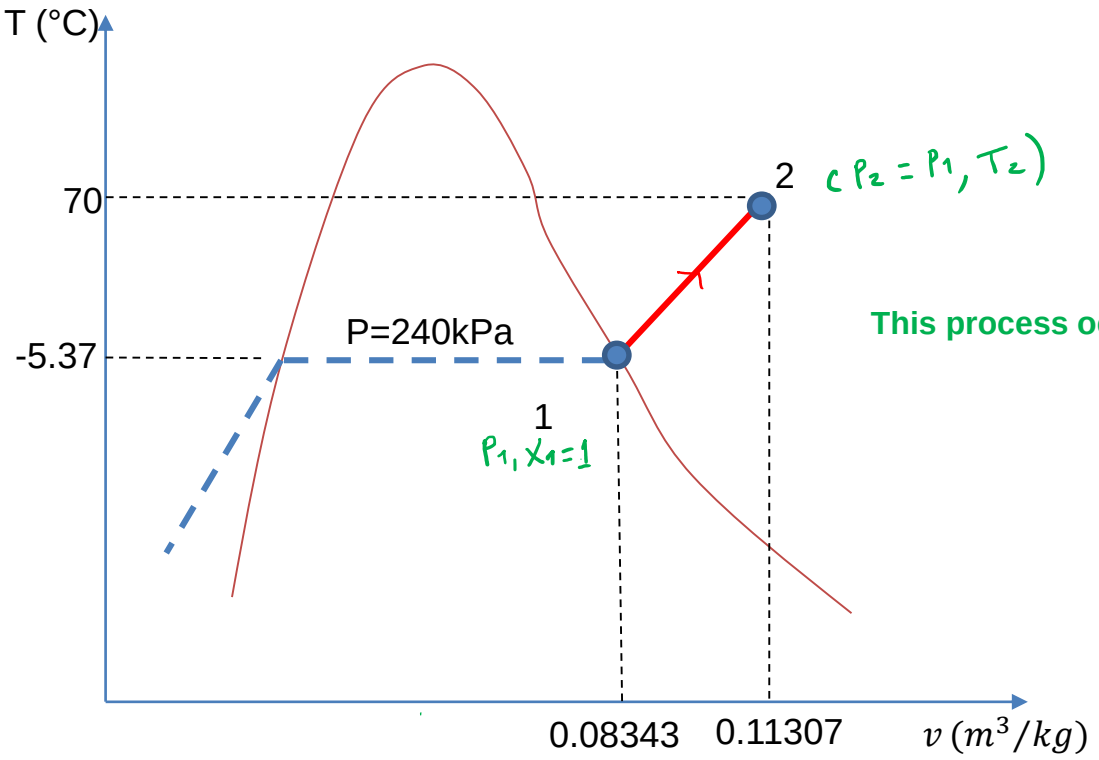
c) $W_b = P(V_2 - V_1)$ ? [kJ]



# EXAMPLE 3

A mass of 12 kg of saturated refrigerant-134a vapor is contained in a piston–cylinder device at 240 kPa. Now 300 kJ of heat is slowly (quasistatic) transferred to the refrigerant at constant pressure while a 110-V source supplies current to a resistor within the cylinder for 6 min. Determine the current supplied **(I) [A]** if the final temperature is 70°C. Also, show the process on a **T**[°C]-**v**[$m^3/kg$)] diagram.






This process occurs at p = constant.

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State 1:

$P_1 = 240\ kPa$

$T_1 = T_{sat} = -5.37°C$

$v_1 = 0.08343\ m^3/s$

$u_1 = 224.07\ kJ/kg$

**TABLE A-12**

**Properties of Superheated Refrigerant 134a**

| $T$ °C | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K |
|---|---|---|---|---|
| $p = 2.4$ bar $= 0.24$ MPa ($T_{sat} = -5.37°C$) | | | | |
| Sat. | 0.08343 | 224.07 | 244.09 | 0.9222 |
| 70 | 0.11307 | 286.35 | 313.49 | 1.1501 |

State 2:

$P_2 = 240\ kPa$

$T_2 = 70°C$

$v_2 = 0.11307\ m^3/s$

$u_2 = 286.35\ kJ/kg$

$$\Delta U = Q - W$$

$$m(u_2 - u_1) = Q - (W_{elec} + W_b)$$

$W_{pv}$

$$m(u_2 - u_1) = Q - \left(-VIt + mP(v_2 - v_1)\right)$$

$$12 \times (286.35 - 224.07) = 300 + \frac{110 \times I \times (6 \times 60)}{1000} - 12 \times 240 \times (0.11307 - 0.08343)$$

$$\boxed{I = 13.4526\ A}$$

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State 1:

$P_1 = 240\ kPa$

$T_1 = T_{sat} = -5.37°C$

$v_1 = 0.08343\ m^3/s$

$u_1 = 224.07\ kJ/kg$

$\boldsymbol{h_1 = 244.09\ kJ/kg}$

**TABLE A-12**

**Properties of Superheated Refrigerant 134a**

| $T$ °C | $v$ m³/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg · K |
|---|---|---|---|---|
| $p = 2.4$ bar $= 0.24$ MPa ($T_{sat} = -5.37°C$) | | | | |
| Sat. | 0.08343 | 224.07 | 244.09 | 0.9222 |
| 70 | 0.11307 | 286.35 | 313.49 | 1.1501 |

State 2:

$P_2 = 240\ kPa$

$T_2 = 70°C$

$v_2 = 0.11307\ m^3/s$

$u_2 = 286.35\ \frac{kJ}{kg}$

$\boldsymbol{h_2 = 313.49\ kJ/kg}$

$$\Delta H = Q - W_{elec}$$

$$m(h_2 - h_1) = Q - W_{elec}$$

$$m(h_2 - h_1) = Q - (-VIt)$$

$$12 \times (\mathbf{313.49} - \mathbf{244.09}) = 300 + \frac{110 \times I \times (6 \times 60)}{1000}$$

$$\boxed{I = 13.4545\ A}$$

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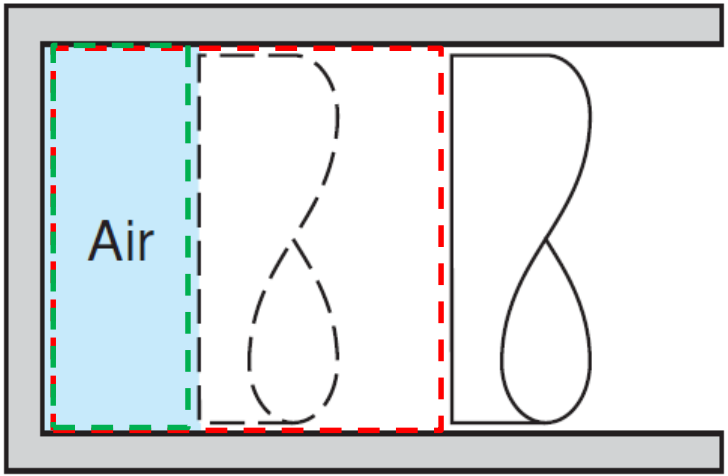
EXAMPLE 8.3: A piston/cylinder assembly in a car contains 0.2 L of air (ideal gas) at 90 kPa and 293 K, as shown in figure. The air is compressed in a quasi-equilibrium polytropic process ($PV^n$) with polytropic exponent $n$ = 1.25 to a final volume six times smaller. Determine the final pressure and temperature, and the heat transfer for the process.



**State 1**

$P_1 = 90\ kPa$

$V_1 = 0.2L = 0.2 \times 10^{-3}\ m^3$

$T_1 = 293K$

$m_1 = \frac{P_1 V_1}{RT_1} = \frac{90 \times 0.2 \times 10^{-3}}{0.287 \times 293} = 2.141 \times 10^{-4} kg$

**State 2**

$P_2 = ?\ kPa$

$V_2 = \frac{1}{6} \times 0.2L = \frac{1}{30} L = \frac{1}{30} \times 10^{-3}\ m^3$

$T_2 = ?\ °C$

Polytropic process:

$$P_1 V_1^n = P_2 V_2^n \rightarrow 90 \times 0.2^{1.25} = P_2 \times \left(\frac{1}{30}\right)^{1.25}$$

Lo importante es que el volumen este en las mismas unidades

$$P_2 = 845.1457\ kPa$$

Final temperature:

$$T_2 = \frac{P_2 V_2}{mR} = \frac{845.1457 \times \frac{1}{30} \times 10^{-3}}{2.141 \times 10^{-4} \times 0.287} = 458.4709\ K$$

$\Delta U = Q - W$

? ?

Polytropic work:

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-n}\,dV = C\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{1-n}$$

$$W = \frac{845.1457 \times \frac{1}{30} \times 10^{-3} - 90 \times 0.2 \times 10^{-3}}{1 - 1.25}$$

$$\boxed{W = -40.686 \times 10^{-3}\ kJ}$$

Energy balance for closed systems:

$$\Delta U = Q - W$$

$$m(u_2 - u_1) = Q - W$$

TABLE A-20

Ideal Gas Specific Heats of Som

| Temp. K | $c_p$ | $c_v$ | $k$ |
|---|---|---|---|
| | Air | | |
| 350 | 1.008 | 0.721 | 1.398 |
| 400 | 1.013 | 0.726 | 1.395 |

$$T_{avg} = \frac{293 + 458.4709}{2} = 375.7355K$$

$$c_{v\_avg} = 0.7236\frac{kJ}{kgK}$$

$$2.141 \times 10^{-4} \times 0.7236 \times (458.4709 - 293) = Q - (-40.686 \times 10^{-3})$$

$$\boldsymbol{Q} = -15.0508 \times 10^{-3}\ kJ$$

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Usar la Tabla A-23

458.4709

**TABLE A-22**

**Ideal Gas Properties of Air**

| $T$(K) | $h$ | $u$ | $s^\circ$ | when $\Delta s = 0$: $p_r$ | $v_r$ | $T$ | $h$ | $u$ | $s^\circ$ |
|---|---|---|---|---|---|---|---|---|---|
| 200 | 199.97 | 142.56 | 1.29559 | 0.3363 | 1707. | 450 | 451.80 | 322.62 | 2.11161 |
| 210 | 209.97 | 149.69 | 1.34444 | 0.3987 | 1512. | 460 | 462.02 | 329.97 | 2.13407 |
| 220 | 219.97 | 156.82 | 1.39105 | 0.4690 | 1346. | 470 | 472.24 | 337.32 | 2.15604 |
| 230 | 230.02 | 164.00 | 1.43557 | 0.5477 | 1205. | 480 | 482.49 | 344.70 | 2.17760 |
| 240 | 240.02 | 171.13 | 1.47824 | 0.6355 | 1084. | 490 | 492.74 | 352.08 | 2.19876 |
| 250 | 250.05 | 178.28 | 1.51917 | 0.7329 | 979. | 500 | 503.02 | 359.49 | 2.21952 |
| 260 | 260.09 | 185.45 | 1.55848 | 0.8405 | 887.8 | 510 | 513.32 | 366.92 | 2.23993 |
| 270 | 270.11 | 192.60 | 1.59634 | 0.9590 | 808.0 | 520 | 523.63 | 374.36 | 2.25997 |
| 280 | 280.13 | 199.75 | 1.63279 | 1.0889 | 738.0 | 530 | 533.98 | 381.84 | 2.27967 |
| 285 | 285.14 | 203.33 | 1.65055 | 1.1584 | 706.1 | 540 | 544.35 | 389.34 | 2.29906 |
| 290 | 290.16 | 206.91 | 1.66802 | 1.2311 | 676.1 | 550 | 554.74 | 396.86 | 2.31809 |
| 295 | 295.17 | 210.49 | 1.68515 | 1.3068 | 647.9 | 560 | 565.17 | 404.42 | 2.33685 |

293 K

```
# ========================
# RESULTADOS
# ========================
print("Interpolación de energías internas")
print("u1 =", u1, "kJ/kg")
print("u2 =", u2, "kJ/kg")

print("\nPrimera ley")
print("W =", W, "kJ")
print("Q =", Q, "kJ")
```

```
Interpolación de energías internas
u1 = 209.058 kJ/kg
u2 = 328.8461 kJ/kg

Primera ley
W = -0.040686 kJ
Q = -0.015039 kJ
```

$$\Delta U = Q - W$$

$$m(u_2 - u_1) = Q - W$$

$$2.141 \times 10^{-4} \times (328.8461 - 209.058) = Q - (-40.687 \times 10^{-3})$$

$$Q = -15.039 \times 10^{-3}\ kJ$$

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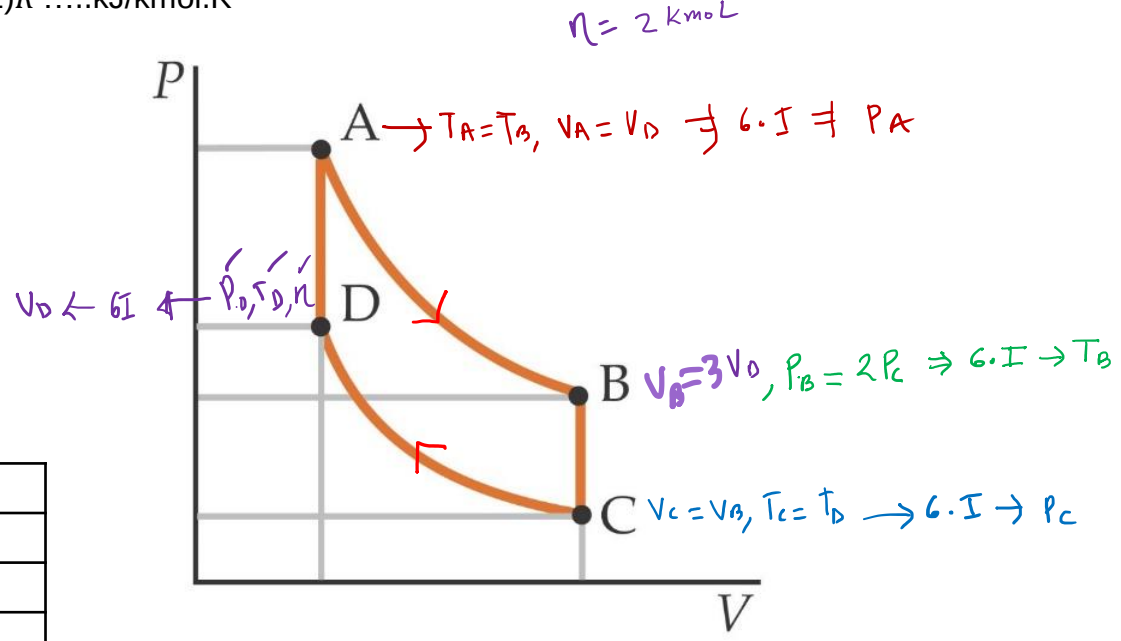
# 4.The First Law of Thermodynamics. Cyclic Processes. P-V Diagrams

At point D in figure the pressure and temperature of 2 kmol of an ideal monoatomic gas are 2 atm and 360 K. The volume of the gas at point B on the PV diagram is three times that at point D and its pressure is twice that a point C. Paths AB and DC represent isothermal processes. The gas is carried through a complete cycle along the path DABCD. Determine the total work done by the gas and the heat supplied to the gas along each portion of the cycle. Cv = (3/2)$\overline{R}$ …..kJ/kmol.K




| State | P | V | T |
|---|---|---|---|
| | (kPa) | ($m^3$) | (K) |
| A | | | |
| B | | | |
| C | | | |
| D | | | |

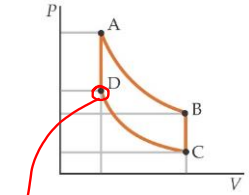
# The First Law of Thermodynamics. Cyclic Processes. P-V Diagrams

At point D in figure the pressure and temperature of 2 kmol of an ideal monoatomic gas are 2 atm and 360 K. The volume of the gas at point B on the PV diagram is three times that at point D and its pressure is twice that a point C. Paths AB and DC represent isothermal processes. The gas is carried through a complete cycle along the path DABCD. Determine the total work done by the gas and the heat supplied to the gas along each portion of the cycle. Cv = (3/2)$\bar{R}$ …..kJ/kmol.K

*We can find temperatures, pressures and volumes at all points for this idea monoatomic gas (3 degrees of freedom) using the ideal-gas law and the work for each process by finding the areas under each curve. We can find de heat exchanged for each process from de heat capacities and the initial and final temperatures for each process.*

Total work done by the gas

$$W_{tot} = W_{D\to A} + W_{A\to B} + W_{B\to C} + W_{C\to D}$$




Todo conocido excepto $V_D$

Volume of state D

$$V_D = \frac{n\bar{R}T_D}{P_D}$$

$$V_D = \frac{2 \times 8.314 \times 360}{2 \times 101.3}$$

dato; dato; atm to kpa

$$V_D = 29.5463\ \mathrm{m}^3$$

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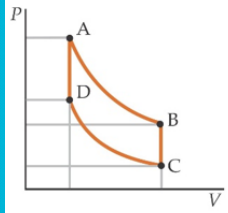


**Defining state C**

$V_C = V_B = 3V_D$ (Isoterma, dato)

$V_C = 88.6389\ \text{m}^3$

$T_C = T_D = 360\ \text{K}$ (Isoterma)

$$P_C = \frac{n\bar{R}T_C}{V_C} = \frac{2 \times 8.314 \times 360}{88.6389}$$

$P_C = 67.5333\ \text{kPa}$

**Defining state B**

$P_B = 2P_C = 135.0666\ \text{kPa}$

$$T_B = \frac{P_B V_B}{n\bar{R}} = \frac{135.0666 \times 88.6389}{2 \times 8.314}$$ ($V_B = V_C$)

$T_B = 719.9997\ \text{K}$

**Defining state A**

$T_A = T_B = 719.9997\ \text{KK}$

$V_A = V_D = 29.5463\ \text{m}^3$

$$P_A = \frac{n\bar{R}T_A}{V_A} = \frac{2 \times 8.314 \times 719.9997}{29.5463}$$

$P_A = 405.1998\ \text{kPa}$

| State | P | V | T |
|---|---|---|---|
| | (kPa) | ($m^3$) | (K) |
| A | 405.1998 | 29.5463 | 719.9997 |
| B | 135.0666 | 88.6389 | 719.9997 |
| C | 67.5333 | 88.6389 | 360 |
| D | 202.60 | 29.5463 | 360 |

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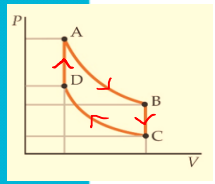


Path D-A
(V = constant)

$W_{D-A} = 0$ kJ

$\Delta U_{D-A} = Q_{D-A} - W_{D-A}$

$nc_v\Delta T = Q_{D-A} - 0$

$$Q_{D-A} = 2 \times \left(\frac{3}{2} \times 8.314\right) \times (719.9997 - 360)$$

$Q_{D-A} = 8979.1125$ kJ

Path B-C
(V = constant)

$W_{B-C} = 0$ kJ

$\Delta U_{B-C} = Q_{B-C} - W_{B-C}$

$nc_v\Delta T = Q_{B-C} - 0$

$$Q_{B-C} = 2 \times \left(\frac{3}{2} \times 8.314\right) \times (360 - 719.9997)$$

$Q_{B-C} = -8979.1125$ kJ

Path A-B
(T = constant)

$\Delta U_{A-B} = 0$ kJ

$0 = Q_{A-B} - W_{A-B}$

$$Q_{A-B} = n\bar{R}T_{A-B} \ln\frac{V_B}{V_A}$$

$$Q_{A-B} = 2 \times 8.314 \times 719.9997 \times \ln\frac{88.6389}{29.5463}$$

$Q_{A-B} = 13152.7566$ kJ

Path C-D
(T = constant)

$\Delta U_{C-D} = 0$ kJ

$0 = Q_{C-D} - W_{C-D}$

$$Q_{C-D} = n\bar{R}T_{C-D} \ln\frac{V_D}{V_C}$$

$$Q_{C-D} = 2 \times 8.314 \times 360 \times \ln\frac{29.5463}{88.6389}$$

$Q_{C-D} = -6576.3810$ kJ

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# The First Law of Thermodynamics. Cyclic Processes. P-V Diagrams

Summarizing

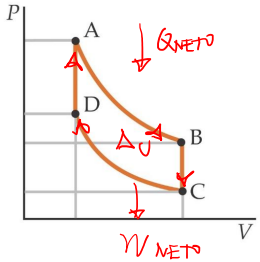
| Proceso | Q (kJ) | W (kJ) | ΔU (kJ) |
|---|---|---|---|
| D→A (isócoro) | 8979.1125 | 0 | 8979.1125 |
| A→B (isotérmico) | 13152.7566 | 13152.7566 | 0 |
| B→C (isócoro) | -8979.1125 | 0 | -8979.1125 |
| C→D (isotérmico) | -6576.381 | -6576.381 | 0 |

Total work done by the gas

$$W_{tot} = W_{D\to A} + W_{A\to B} + W_{B\to C} + W_{C\to D}$$

$$W_{tot} = 0 + 13152.7566 + 0 + (-6576.381)$$

$$W_{tot} = 6576.3756 \text{ kJ}$$




$\Delta U = Q_{NETO} - W_{NETO} \Rightarrow Q_{NETO} = W_{NETO}$ (0 → ciclo)

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Thanks!