Thermodynamic

2026-1

NEDHER SÁNCHEZ RAMÍREZ

NAUDY LOPEZ

Work-Heat-First Law_Control mass_S_{5_2}

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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						

Link de WhatsApp de Termodinámica:

https://chat.whatsapp.com/Iu3b3wnWFuY2Zvamn89NNa

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 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 %**

Se subirá al EDU En dos bloques de 25% c/u

Thermodynamics _ Evaluation

Tarea grupal (proyecto)…..

La actividad consta del análisis de una sistema, dicho análisis puede requerir elementos de programación.

Fechas de entrega del laboratorio:
1ra entrega - 18/05/2026 a las 9 am (jueves de la semana 9)
2da entrega - 15/06/2026 a las 9am (lunes de la semana 13)
coevaluación - 16/06/2026 a las 11:59pm (martes de la semana 13)

Link con toda la información de la tarea grupal :

https://docs.google.com/spreadsheets/d/1DMrZjoEaRlHfZPbrFa5q84ha0ElWJQS1zmyLanvjGcw/edit?gid=0#gid=0

Thermodynamics _ Evaluation

Link con las rubricas de actividad de aula y tarea individual:

https://docs.google.com/spreadsheets/d/1iLMFoTAZiUBYuD8fGZFW4d0pF0-UBt8f/edit?gid=85594443#gid=85594443

Session 9-10: Describe the concepts of energy, heat and work and relate them to the principle of conservation of energy (first law of thermodynamics).

Thermodynamics is built on 3 empirical laws

0^{th} Law $\Rightarrow$ Defines Temperature (T)

1^{st} Law $\Rightarrow$ Defines Energy (E,U)

2^{nd} Law $\Rightarrow$ Defines Entropy (S)

ENERGY

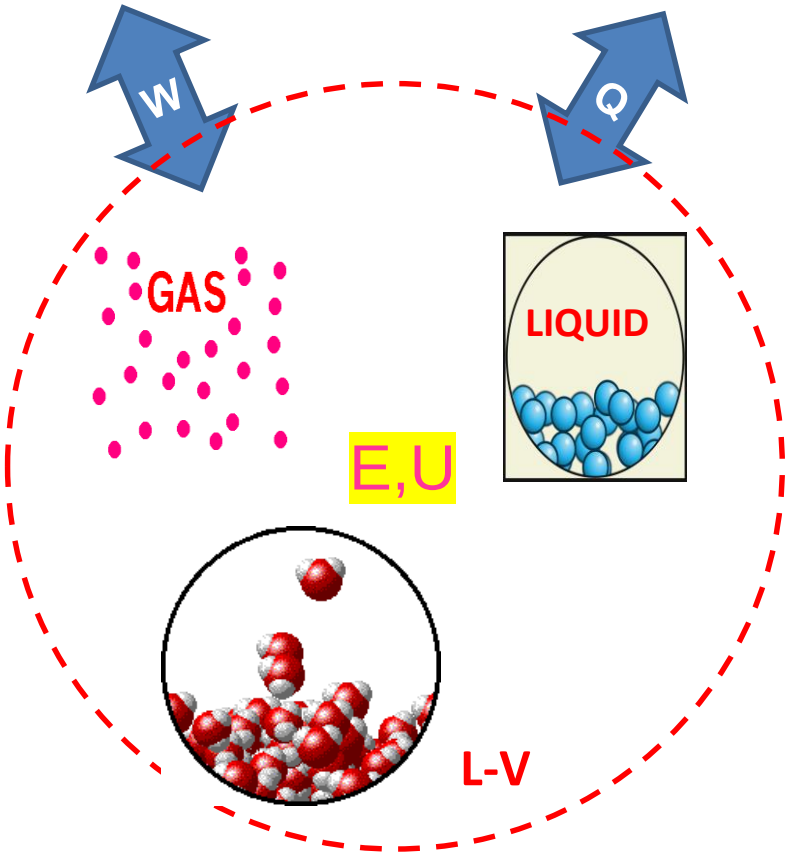
A macroscopic amount of mass can possess energy in the form of **internal energy** inherent in its internal structure, **kinetic energy** in its motion, and **potential energy** associated with external forces acting on the mass (g).

$$E = \text{Internal} + \text{Kinetic} + \text{Potential} = U + \text{KE} + \text{PE}$$

$$e = E/m = u + ke + pe = u + {}^{1}\!/_{2}V^{2} + gz$$

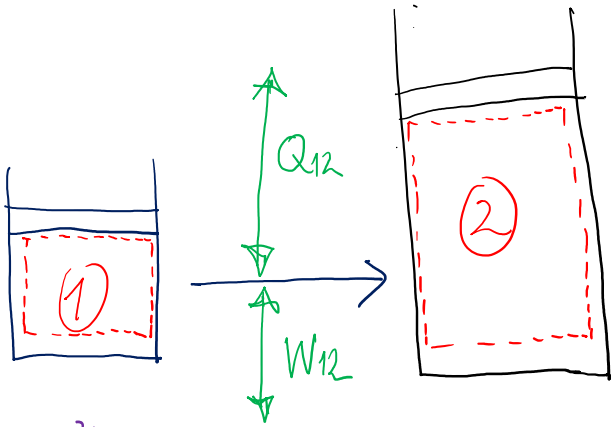
Mass control

Work-Heat- First Law



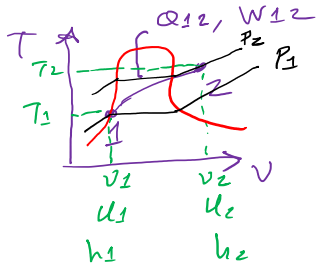
$$E_2 - E_1 = Q - W$$

* Energy can cross the boundary of a system in two distinct forms: ***heat*** and ***work***



v_1
u_1
h_1
T_1

v_2
u_2
h_2
T_2



Pueden haber varios Q y W.

1ra ley:

$\Delta U = Q - W$

si hay varios Q y W

$\Delta U = Q_{NETO} - W_{NETO}$ ó

$\Delta U = Q_1 + Q_2 - W_1 - W_2$ ETC.

$\Delta U = \Delta E$?

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

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

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

(2) Despejamos de la ecuación (*)

(3) Despejamos o Lo hallamos analítico (semana 6)

- $W_e = IVt$
- $W_{pv} = \int P_{proj} dv$

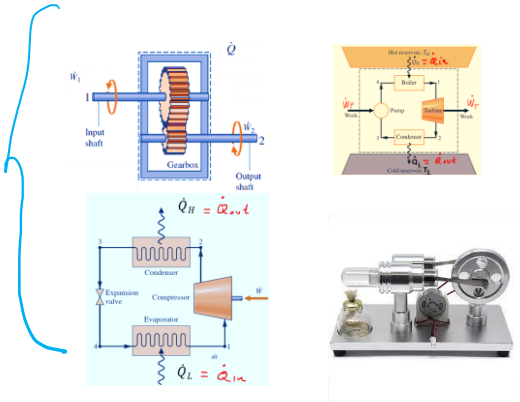
↳ Ya Lo vimos
- Resorte lineal
- $P = cte$
- $PV = cte$
- $PV^n = cte$

Hoy veremos la regla de los signos para la ecuación (*) además de encontrar Q, W_{pv}, ΔU

Para procesos que ocurren continuamente.

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

↳ La vimos el Lunes, La aplicaremos en La semana 6



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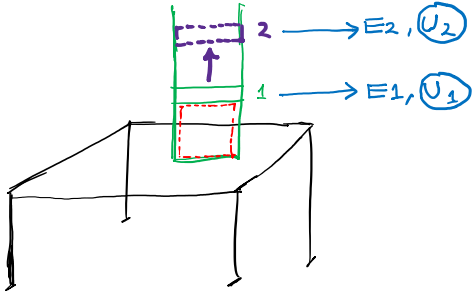
Energy Accounting: Energy Balance for Closed Systems

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

$$E_2 - E_1 = Q - W$$

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



Ya sabemos calcular ΔU para sustancias tabuladas y para gases ideales.

$$\Delta \tilde{E}^{U} = Q_{NETO} - W_{NETO} \quad (1)$$

$Q_i \rightarrow$
- Dato
- de EC. (1)

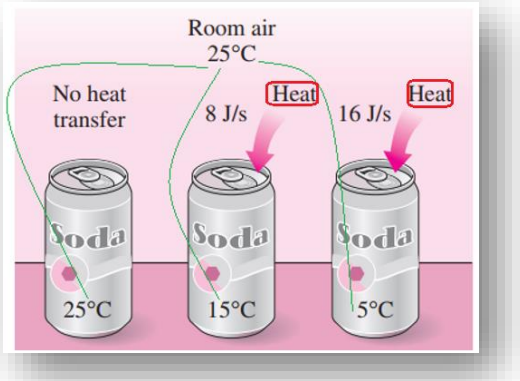
$W \rightarrow$
- Dato
- de EC (1)
- Analíticamente
  - $\int p\,dv$
  - Eléctrico

HOW CAN A SYSTEM EXCHANGE ITS ENERGY?

* Energy can cross the boundary of a system in two distinct forms: ***heat*** and ***work***

a) Heat

Heat is defined as *the form of energy that is transferred between two systems (or a system and its surroundings) by virtue of a temperature difference:*



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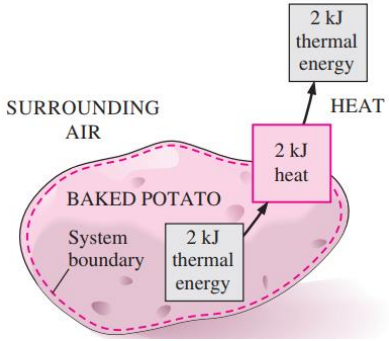
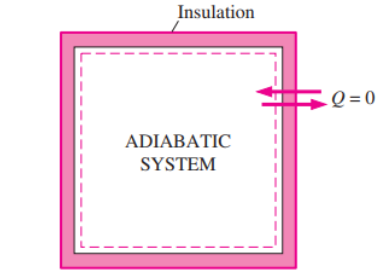
HOW CAN A SYSTEM EXCHANGE ITS ENERGY?

a) Heat

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





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

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

$$Q = \int_{t_1}^{t_2} \dot{Q}\, dt \quad \text{(kJ)}$$

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

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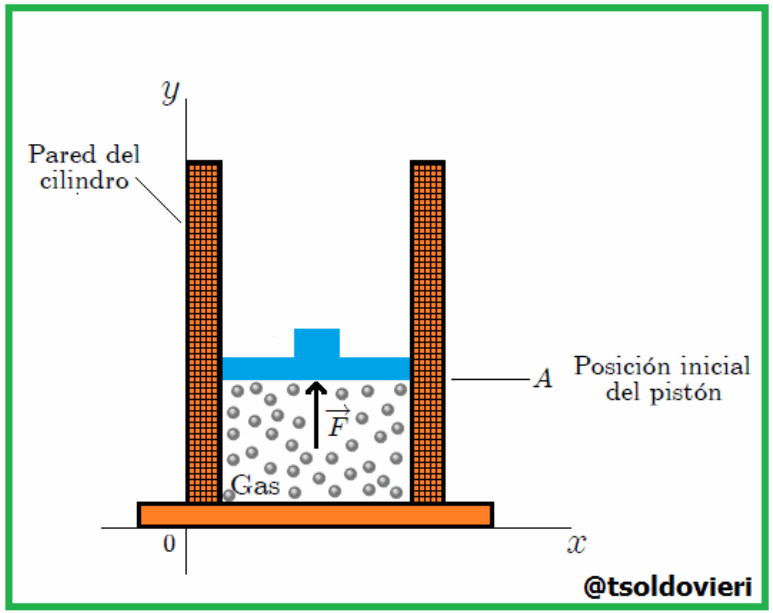
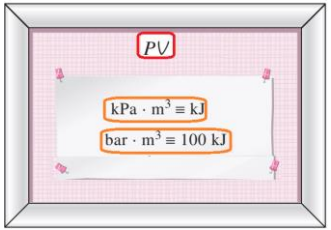
- **DEFINITION: b) Work -- is done by a system (on its surroundings) if the sole effect on everything external to the system could have been the raising of a weight**



https://hive.blog/stem-espanol/@tsoldovieri/gas-ideal-gas-real-y-el-trabajo-realizado-por-un-gas

$$\delta W = PA\,dx \rightarrow \delta W = P\,dV \rightarrow W = \int_1^2 P\,dV$$



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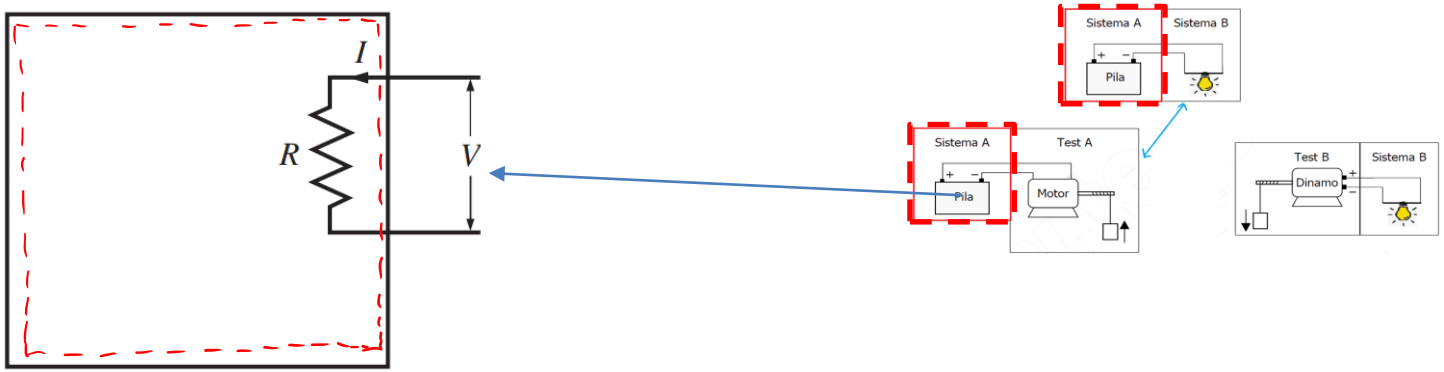


When both **V** and I remain constant during the time interval Δt

$\dot{W}_e = \mathbf{V}I$ (W) (J/s = W)

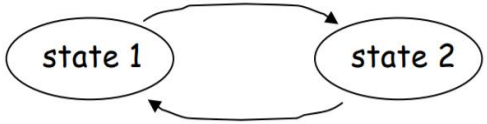
$W_e = \mathbf{V}I\,\Delta t$ (J)

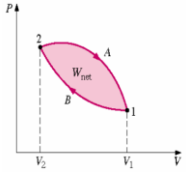
Work, Heat, and the First Law

WORK

Work (w) is not a function of state.

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

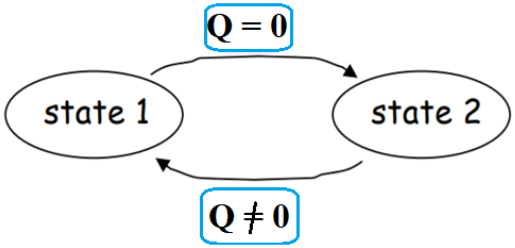




$$\oint \delta W = \oint PdV \neq 0$$

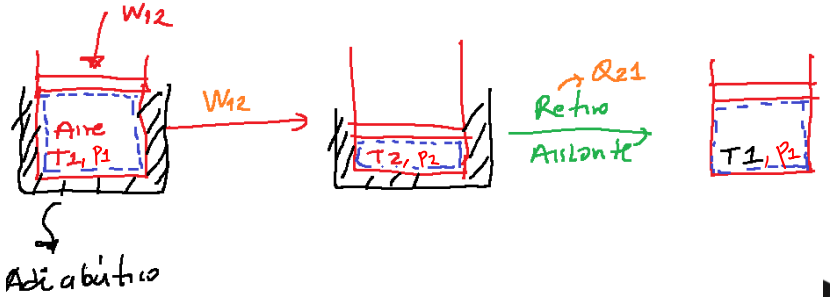
HEAT

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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The Moving Boundary Work (PV -Work)

In determining the integral: $W = \int_1^2 P_{syst}\, dV$

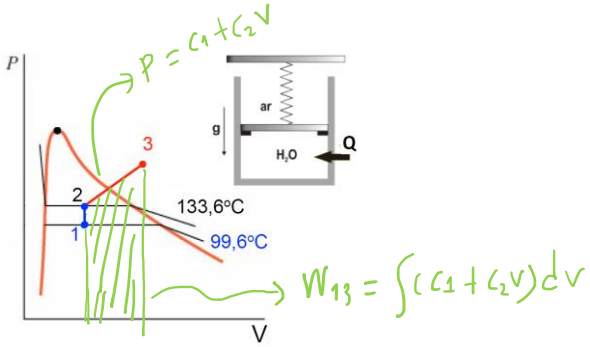
★ If the process is reversible or quasiestatic the relation P_{syst}-V is easy to obtain for simple process:

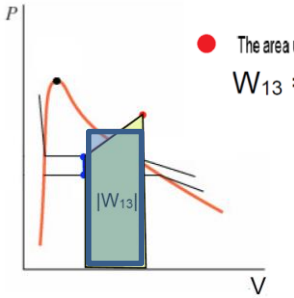
- Recta lineal
- P = cte
- PV = cte
- PV^n = cte

Integrando

$$W = \int_1^2 P_{syst}\, dV$$

Geometricamente (cuando se puede)





- The area under the process curve (a trapezoid) is determined to be:

$W_{13} = (P_3+P_2)(V_3-V_2)/2 = 175kJ$

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Poll

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

P = cte

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

$PV^n = cte$

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

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

→ UNIVERSAL

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

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

↳ GAS IDEAL

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

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

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

↳ GAS IDEAL

* RESORTE LINEAL ↳ UNIVERSAL

$P = C_1 + C_2V$

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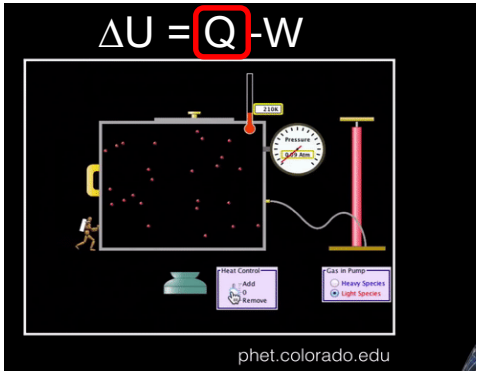
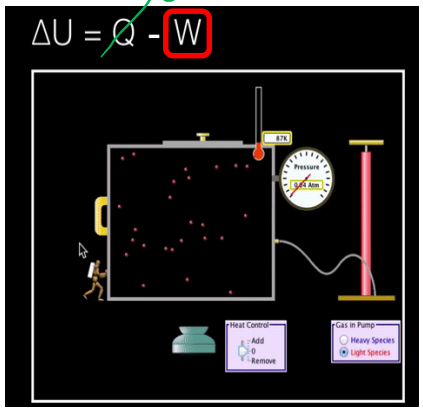
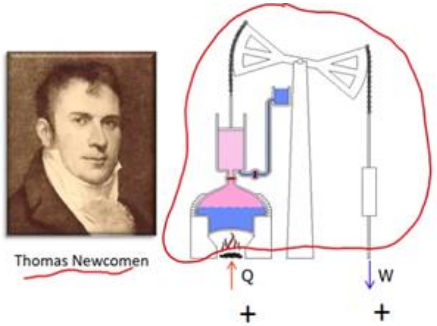
Work, Heat, and the First Law_ Closed system

Let's assume $\Delta V = 0$



Let's assume adiabatic process





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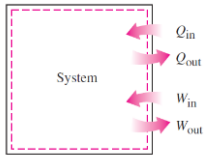
First law of thermodynamics _Closed system_ Multiple inputs

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

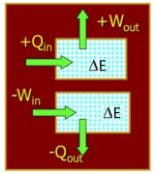
$$(Q_{in} - Q_{out}) + (W_{in} - W_{out}) = \Delta E_{system}$$ or $$Q_{NET} - W_{NET} = \Delta E$$

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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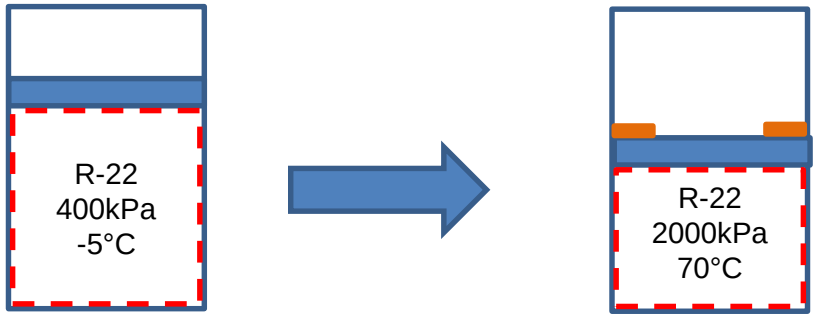
EXAMPLE 6.2

10 kilograms of Refrigerant 22 contained in a piston–cylinder assembly undergoes a slow process for which the pressure-specific volume relationship is $Pv^n = constant$. The initial and final states of the refrigerant are fixed by $P_1 = 400\,kPa$, $T_1 = -5°C$, and $P_2 = 2000\,kPa$, $T_2 = 70°C$, respectively. Determine the work and heat transfer for the process, each in kJ.

$$\Delta U = m(u_2 - u_1) = Q - W$$



State 1

TABLE A-9

(Continued)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 4.0 bar = 0.40 MPa (T_{sat} = −6.56°C)			
Sat.	0.05812	224.24	247.48	0.9370
−10				
−5	0.05860	225.16	248.60	0.9411

$P_1 = 4bar$
$T_1 = -5°C$

$v_1 = 0.05860\ m^3/kg$
$u_1 = 225.16\ kJ/kg$

State 2

TABLE A-9

(Continued)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 20.0 bar = 2.00 MPa (T_{sat} = 51.26°C)			
Sat.	0.01124	239.51	261.98	0.8586
60	0.01212	247.20	271.43	0.8873
70	0.01300	255.35	281.36	0.9167
80	0.01381	263.12	290.74	0.9436
90	0.01457	270.67	299.80	0.9689

$P_2 = 20bar$
$T_2 = 70°C$

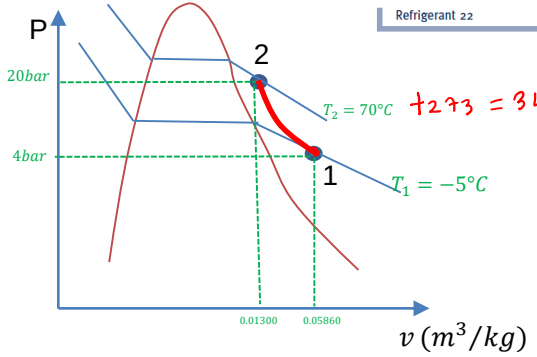
$v_2 = 0.01300\ m^3/kg$
$u_2 = 255.35\ kJ/kg$

TABLE A-1

Atomic or Molecular Weights and Critical Properties of Selected Elements and Compounds

Substance	Chemical Formula	M (kg/kmol)	T_c (K)	p_c (bar)	$Z_c = \frac{p_c v_c}{R T_c}$
Refrigerant 22	$CHClF_2$	86.48	369	49.8	0.267

$+273 = 343 < 369$



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Calculating "n"

$$P_1 v_1^n = P_2 v_2^n$$

$$\frac{P_1}{P_2} = \left(\frac{v_2}{v_1}\right)^n \rightarrow \frac{4}{20} = \left(\frac{0.01300}{0.05860}\right)^n \rightarrow n = 1.0688$$

The work is:

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-n}\,dV = C\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{1-n} \quad (\text{kJ}) \quad n \neq 1$$

V = v*m

Ten kilograms

$$W = \frac{2000 \times 0.01300 * 10 - 400 \times 0.05860 * 10}{1 - 1.0688} = -372.093\ kJ$$

Work is negative because it is a compression

First law for closed systems (neglecting potential and kinetic energy):

$$\Delta U = Q - W$$

$$m(u_2 - u_1) = Q - W \rightarrow 10 \times (255.35 - 225.16) = Q - (-372.093)$$

$$Q = -70.193\ kJ$$

The heat is negative because it is outgoing.

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CAMINO 1

$\Delta U = Q_{12_{NETO}} - W_{12_{NETO}}$

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

$Q_{12} = m(u_2 - u_1) + W_{12}$ ($W_{12} = -372.09$ KJ)

$Q_{12} = m(u_2 - u_1) - 372.09$

$Q_{12} = -70.19$ KJ

Como esta ecuación toma en cuenta la convención de signos, el $Q_{NETO} = Q_{12}$, y me indica si el calor esta entrando o saliendo.

CAMINO 2

$\Delta U = W_{in} - W_{out} + Q_{int} - Q_{out}$

El enunciado no dice nada pero supongamos dice que no hay entrada de calor.

$\Delta U = W_{in} - W_{out} + Q_{in} - Q_{out}$

$\Delta U = W_{in} - Q_{out}$

$Q_{out} = W_{in} - \Delta U$

$= 372.09 - 10(255.35 - 225.16)$

$= 70.19$ KJ

In this case the values are always positive because the orientation is given by the word “in” or “out”

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Cuando estoy usando el camino 2 y no se el Q (o W) entra o sale, puedo plantear la EC con Q_{NETO} (o W_{NETO})

$$\Delta U = W_{in} - W_{out} + Q_{in} - Q_{out}$$

Q_{NET}

I don't know IF it is entering or not

$$\Delta U = W_{in} + Q_{NET}$$

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

$$Q_{NET} = m(u_2 - u_1) - 372.04$$

→ introduced without sign (W_{in})

$$Q_{NET} = -70.19 \text{ KJ}$$

We knew that it was a single Q, as it was not specified if the heat was **in** or **out**, the Q_{NET} sign tells us if it is **in** or **out**, **in this case it indicates that it is out.**

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Que pasa si en ejercicio anterior, asumo que conozco calor(Q_{out} =79.19 kJ, Q_{in} = 0), y que $\Delta u = 301.9\text{kJ}$ si calculo un trabajo neto? Con que signo saldría?

$$\Delta U = \cancel{Q_{in}} - Q_{out} \quad + W_{in} - W_{out}$$

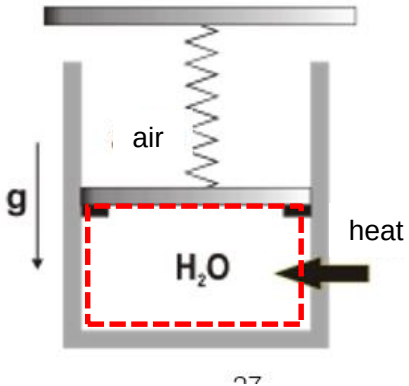
$$W_{NETO}$$

EXAMPLE 7.1

A cylinder-piston assembly contains 2 kg of water. The linear spring is compressed in the initial position, so a pressure of 300kPa in the fluid is necessary to lift it. In the initial state the water is at 100 kPa and occupies a volume of 0.5m^3. The heat is transferred until the pressure reaches 500 kPa. It is requested:

a) The temperature and internal energy of the system when the pressure is 100kPa [**state 1**], 300kPa [**state 2**] and 500kPa [**state 3**]
b) The $P - v$ diagram of the process [**state 1, 2 and 3**]
c) The work and the heat transferred during the entire process ($Q_{1\to2\to3}$ and $W_{1\to2\to3}$)

EXTRA INFORMATION: For a volume of **2** m^3 the force exerted by the spring is such that the pressure in the fluid is 600 kPa.



Es 1 $\begin{cases} P_1 \\ V_1 \rightsquigarrow v_1 \end{cases}$

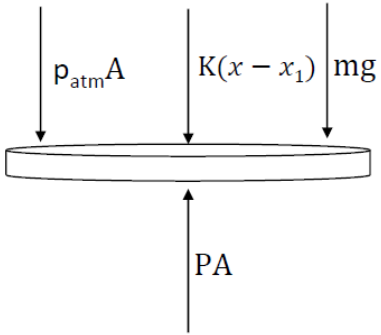
Es 2 $\begin{cases} P_2 \\ V_1 = V_2 \rightsquigarrow v_2 \end{cases}$

Es 3 $\begin{cases} P_3 \\ V_3 \rightarrow ? \end{cases}$

Es 4 $\begin{cases} P_4 = 600kPa \\ V_4 = 2\,m^3 \end{cases}$

Example 7.1:

The body free diagram for the piston is:



For the equilibrium:

$$PA = P_{atm}A + K(x - x_1) + mg$$

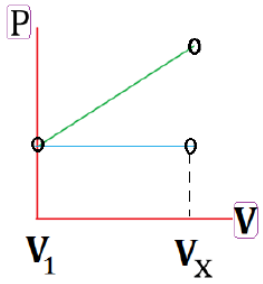
$$P = P_{atm} + \frac{K(x - x_1)}{A} + \frac{mg}{A}$$

$$P = P_{atm} + \frac{mg}{A} + \frac{K(x - x_1)}{A} \times \frac{A}{A}$$

$$P = P_{atm} + \frac{mg}{A} + \frac{K(\mathbf{V - V1})}{A^2}$$

$$P = P_{atm} + \frac{mg}{A} - \frac{K(\mathbf{V1})}{A^2} + \frac{K(\mathbf{V})}{A^2}$$

$$\mathbf{P} = C_1 + C_2\mathbf{V}$$



Pressure is a linear function of volume

Solution

Assumptions:

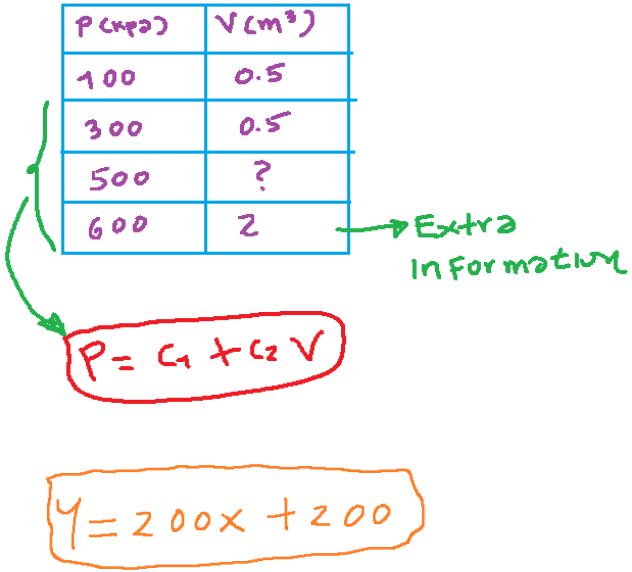
1. The system is the water contained in the cylinder

2. Quasi-equilibrium process

3. States 1, 2 and 3 are in equilibrium

4. The spring is linear

5. Kinetic and potential energy are neglected



Solution

State 1: Defined because we know P and v.

$$v_1 = \frac{0.5}{2} = 0.25\ m^3/kg$$ P1 = 100 kPa

To define state we should check table of saturated water at 100kPa (saturation temperature is 99.63° C) and compare the specific volume. Since: $v_f < v < v_g$ the water is as a liquid-vapor mixture inside the cylinder.

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

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

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
0.80	93.50	1.0380	2.087	391.58	2498.8	391.66	2274.1	2665.8	1.2329	7.4346	0.80
0.90	96.71	1.0410	1.869	405.06	2502.6	405.15	2265.7	2670.9	1.2695	7.3949	0.90
1.00	99.63	1.0432	1.694	417.36	2506.1	417.46	2258.0	2675.5	1.3026	7.3594	1.00

H_2O

Quality: $$x_1 = \frac{v - v_f}{v_g - v_f} = \frac{0.25 - 1.0432 \times 10^{-3}}{1.694 - 1.0432 \times 10^{-3}} = 0.1471$$

Internal energy: $$u_1 = u_f + x_1(u_g - u_f) = 417.36 + 0.147(2506.1 - 417.36) = 724.6137\ kJ/kg$$

Solution

State 2: Defined because we know P and v.

$$v_2 = v_1 = \frac{0.5}{2} = 0.25\ m^3/kg$$ $P_2 = 300\ kPa$

To define state we should check table of saturated water at 300kPa (saturation temperature is 133.6° C) and compare the specific volume. Since: $v_f < v < v_g$ the water is as a liquid-vapor mixture inside the cylinder.

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

Quality:

$$x_2 = \frac{v - v_f}{v_g - v_f} = \frac{0.25 - 1.0732 \times 10^{-3}}{0.6058 - 1.0732 \times 10^{-3}} = 0.4116$$

Internal energy:

$$u_2 = u_f + x_2(u_g - u_f) = 561.15 + 0.4116(2543.6 - 561.15) = 1377.1264\ kJ/kg$$

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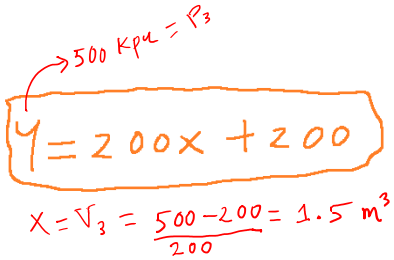
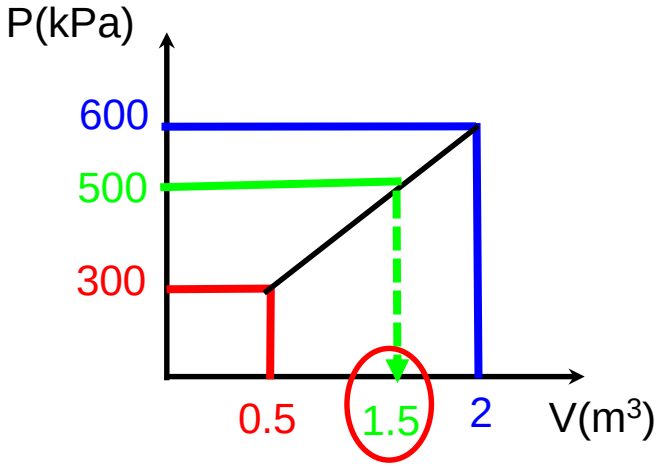
Solution

State 3: Defined but we need to calculate v_3, $P_3 = 500kPa$.

Analyzing the linear spring:





$$v_3 = \frac{1.5}{2} = 0.75\, m^3/kg$$

Solution

State 3: Defined because we know P and v.

To define state we should check table of saturated water at 500kPa (saturation temperature is 151.86˚ C) and compare the specific volume. Since: $v > v_g$ the water is as superheated vapor

TABLE A-4

(Continued)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	$p = 5.0$ bar $= 0.50$ MPa ($T_{sat} = 151.86$°C)			
Sat.	0.3749	2561.2	2748.7	6.8213
180	0.4045	2609.7	2812.0	6.9656
200	0.4249	2642.9	2855.4	7.0592
240	0.4646	2707.6	2939.9	7.2307
280	0.5034	2771.2	3022.9	7.3865
320	0.5416	2834.7	3105.6	7.5308
360	0.5796	2898.7	3188.4	7.6660
400	0.6173	2963.2	3271.9	7.7938
440	0.6548	3028.6	3356.0	7.9152
500	0.7109	3128.4	3483.9	8.0873
600	0.8041	3299.6	3701.7	8.3522
700	0.8969	3477.5	3925.9	8.5952

Interpolating:

T (°C)	v	u
500	0.7109	3128.4
541.9528	**0.750**	3200.2232
600	0.8041	3299.6

$$u_3 = 3200.22\ kJ/kg$$

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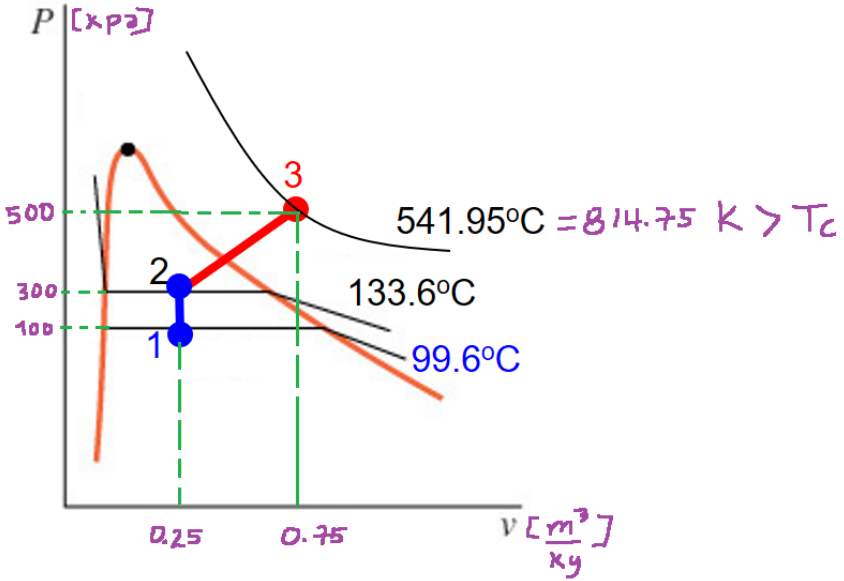
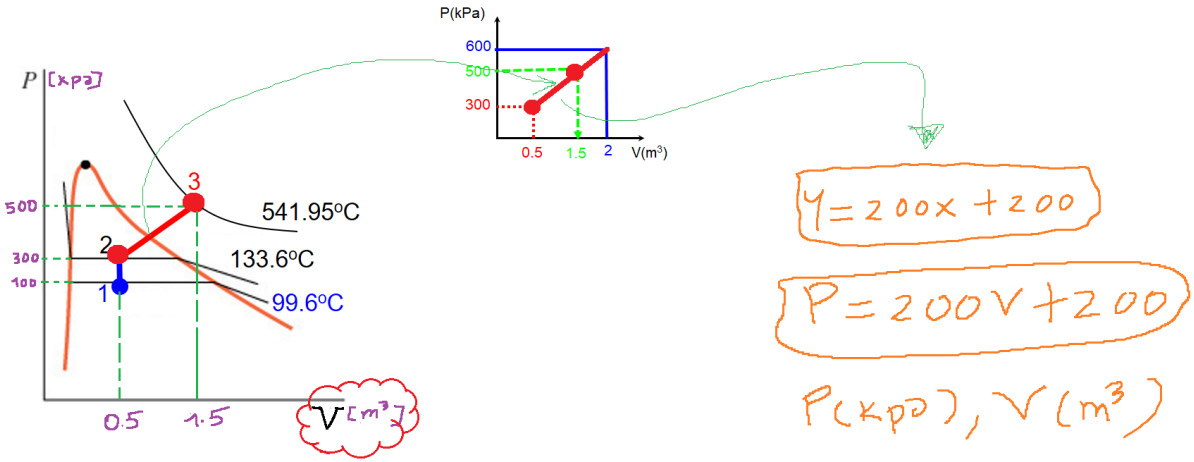
Solution

✦ $P - v$ **diagram.**



✦W_{1_3}?



$Y = 200x + 200$

$P = 200V + 200$

$P(kPa), V(m^3)$

$$W_{1-3} = \int_{V_1}^{V_3} P\,dV = \int_{0.5}^{1.5} (200V + 200)\,dV$$

$$= \frac{200V^2}{2} + 200V \Big]_{0.5}^{1.5}$$

$$= 400\ kJ > 0 \longrightarrow \text{Expansión}$$

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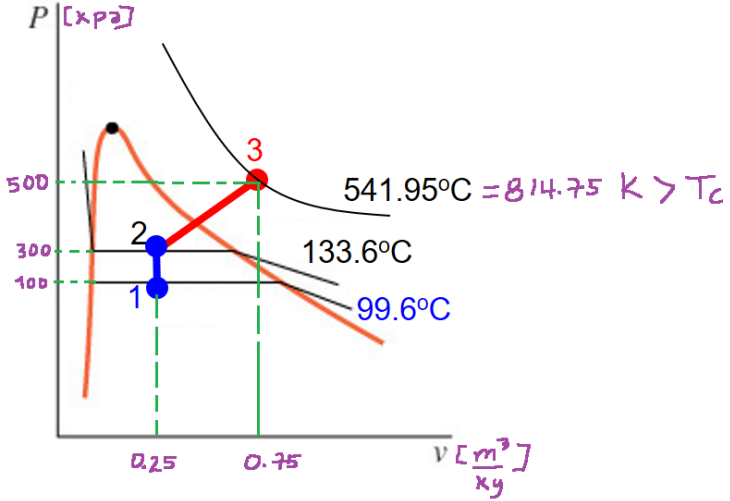
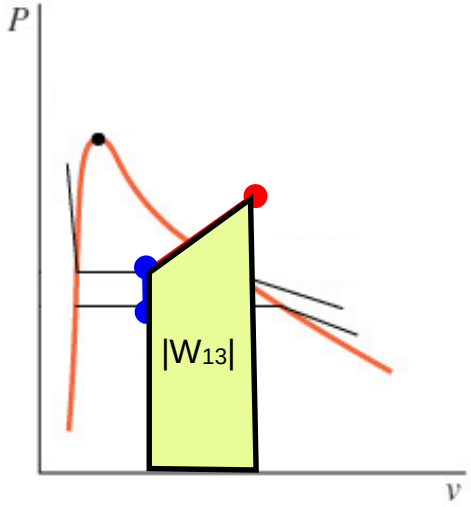
Solution

✦$w_{1\to2\to3}$? **Geometrically**





$$w_{1\to2\to3} = w_{1\to2} + w_{2\to3} = Area = \frac{P_2 + P_3}{2} \times (v_3 - v_2)$$

$$w_{1\to2\to3} = \frac{300 + 500}{2} \times (0.75 - 0.25) = 200 kJ/kg$$

Solution

✦**First law for calculating heat and work**

$$\boldsymbol{W_{1\to2\to3} = w_{1\to2\to3} m = 200\frac{kJ}{kg} \times 2kg = 400kJ}$$

$$\Delta U_{1\to3} = Q_{1\to2\to3} - W_{1\to2\to3}$$

$U_2 - U_1 = Q_{12} + W_{12}$

$U_3 - U_2 = Q_{23} + W_{23}$

$U_3 - U_1 = Q_{123} + W_{123}$

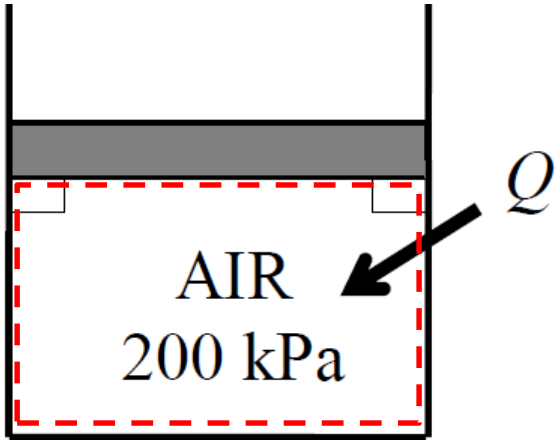
$$Q_{1\to2\to3} = m(u_3 - u_1) + W_{1\to2\to3}$$

$$Q_{1\to2\to3} = 2kg \times (3200.2232 - 724.6137)kJ/kg + 400kJ$$

$$Q_{1\to2\to3} = \mathbf{5351.219\ kJ}$$

EXAMPLE 5.3: A piston–cylinder device, whose piston is resting on a set of stops, initially contains 3 kg of air (ideal gas) at 200 kPa and 26.85 °C (state1). The mass of the piston is such that a pressure of 400 kPa is required to just move it (state2). Heat is now transferred to the air until its volume doubles (state 3). Determine the work done by the air and the total heat transferred to the air during the entire process. Also show the process on a *P[**kPa**]-V[**m³**]* diagram. Use the table A-22

$R = \bar{R}/M$ = 8.314/28.97 = 0.287



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State 1:

$m = 3\ kg$

$P_1 = 200\ kPa$

$T_1 = 26.85°C = 300\ K$

$V_1 = \frac{mRT_1}{P_1} = \frac{3 \times 0.287 \times 300}{200}$

$V_1 = 1.2915\ m^3$

State 2:

$m = 3\ kg$

$P_2 = 400\ kPa$

$V_2 = V_1 = 1.2915\ m^3$

$T_2 = \frac{P_2 V_2}{mR} = \frac{400 \times 1.2915}{3 \times 0.287}$

$T_2 = 600\ K$

State 3:

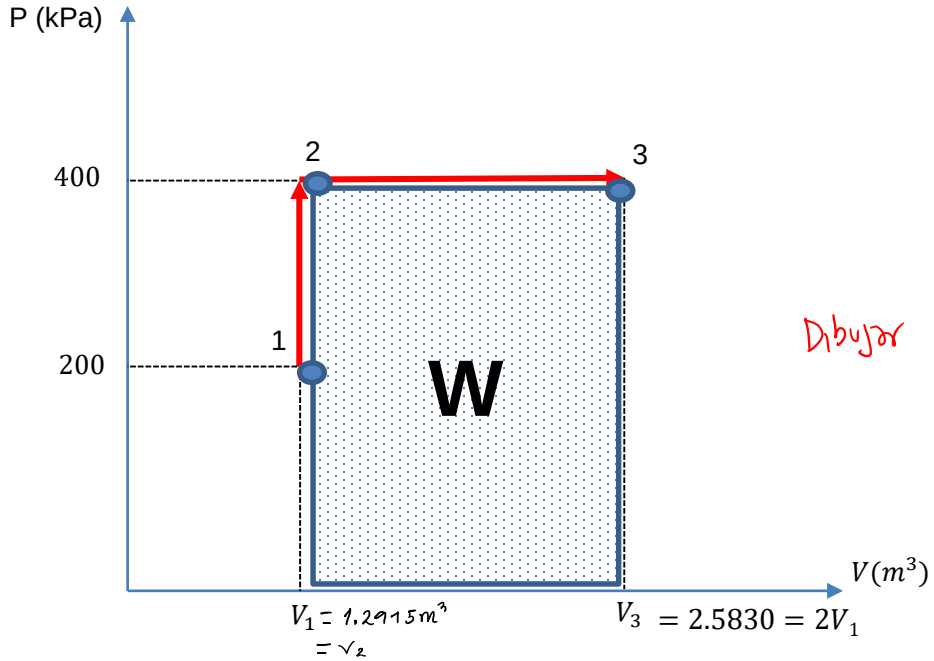
$m = 3\ kg$

$P_3 = P_2 = 400\ kPa$

$V_3 = 2V_2 = 2.5830\ m^3$

$T_3 = \frac{P_3 V_3}{mR} = \frac{400 \times 2.5830}{3 \times 0.287}$

$T_3 = 1200\ K$



Substance	Chemical Formula	M (kg/kmol)
Acetylene	C_2H_2	26.04
Air (equivalent)	—	28.97
Ammonia	NH_3	17.03

Dibujar las isotermas !!!

Energy balance for closed systems, neglecting kinetic and potential energy

$$U_2 - U_1 + U_3 - U_2 = U_3 - U_1 = \Delta U_{123} = m\,\Delta(u_3 - u_1)$$

$$\cancel{W_{12}}^{0} + W_{2-3} = W_{123}$$

$$Q_{12} + Q_{2-3} = Q_{123}$$

TABLE A-22

Ideal Gas Properties of Air

				T(K), h and u(kJ/kg), s° (kJ/kg · K) when $\Delta s = 0^1$	
T	h	u	s°	p_r	v_r
300	300.19	214.07	1.70203	1.3860	621.2
1200	1277.79	933.33	3.17888	238.0	14.470

$$\Delta U_{123} = Q_{123} - W_{123}$$

$$m(u_3 - u_1) = Q_{123} - W_{123}$$

Boundary work

$$m(u_3 - u_1) = Q_{123} - P(V_3 - V_1)$$

$$3 \times (933.33 - 214.07) = Q_{123} - 400 \times (2.5830 - 1.2915)$$

$$Q_{123} = 2674.38\ kJ$$

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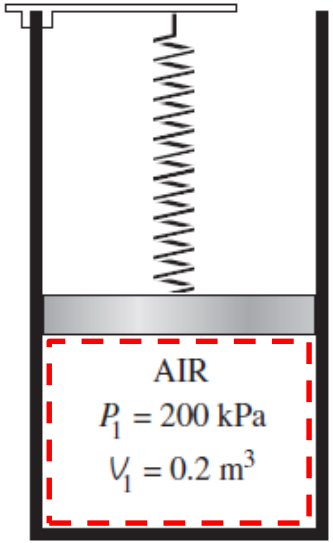
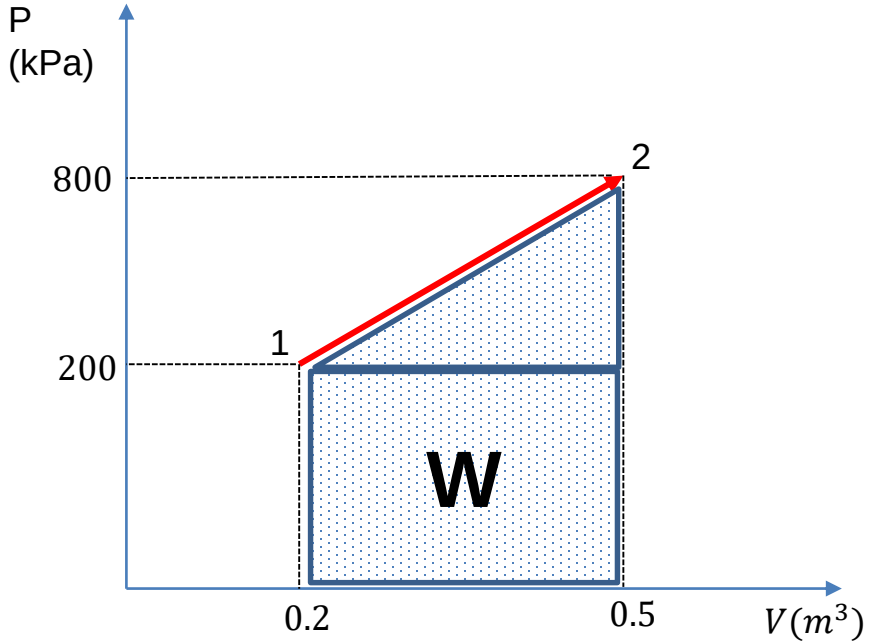
EXAMPLE 6.3

A frictionless piston–cylinder device initially contains air at 200 kPa and 0.2 m^3. At this state, a linear spring ($F \propto x$) is touching the piston but exerts no force on it. The air is now slowly heated to a final state of 0.5 m^3 and 800 kPa. Determine (a) the total work done by the air and (b) the heat transferred during the process. Also, show the process on a P-v diagram. Assume constant c_v at 300K.



State 1:
$P_1 = 200\ kPa$
$V_1 = 0.2\ m^3$

State 2:
$P_2 = 800\ kPa$
$V_2 = 0.5\ m^3$



For a quasistatic process:

$$W = \frac{P_1 + P_2}{2} \times (V_2 - V_1)$$

$$W = \frac{200 + 800}{2} \times (0.5 - 0.2)$$

$$W = 150\ kJ$$

First law for closed systems, neglecting potential and kinetic energy:

TABLE A-20

Ideal Gas Specific Heats of Sor

Temp. K	c_p	c_v	k
	Air		
250	1.003	0.716	1.401
300	1.005	0.718	1.400
350	1.008	0.721	1.398
400	1.013	0.726	1.395
450	1.020	0.733	1.391
500	1.029	0.742	1.387

$$U_2 - U_1 = Q - W$$

$$mc_v(T_2 - T_1) = Q - W$$

$$c_v(mT_2 - mT_1) = Q - W$$

$$c_v\left(\frac{P_2V_2}{R} - \frac{P_1V_1}{R}\right) = Q - W$$

$PV = n\bar{R}T$

$PV = m\frac{\bar{R}}{M}T = mRT$

$\frac{PV}{R} = mT$

$$0.718 \times \left(\frac{800 \times 0.5}{0.287} - \frac{200 \times 0.2}{0.287}\right) = Q - 150$$

$$\boxed{Q = 1050.6272\ kJ}$$

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EXAMPLE 1.2: **A closed rigid tank contains a two-phase liquid–vapor mixture of Refrigerant 22 initially at −20°C with a quality of 50.36%. Energy transfer by heat into the tank occurs until the refrigerant is at a final pressure of 6 bar. Determine the amount of energy transfer by heat, in kJ per kg of refrigerant.**

STATE 1: LV MIXTURE

R-22
-20°C
50.36% Quality

TABLE A-7

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

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

		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy $kJ/kg \cdot K$		
Temp. °C	Press. bar	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	Sat. Liquid s_f	Sat. Vapor s_g	Temp. °C
−20	2.4534	0.7427	0.0926	21.99	219.37	22.17	219.91	242.09	0.0908	0.9595	−20

$$T_1 = -20°C, x_1 = 50.36\%$$
$$v_1 = v_{f1} + x_1(v_{g1} - v_{f1}) = 0.7427 \times 10^{-3} + 0.5036(0.0926 - 0.7427 \times 10^{-3}) = 0.047$$
$$u_1 = u_{f1} + x_1(u_{g1} - u_{f1}) = 21.99 + 0.5036(219.37 - 21.99) = 121.3906\ kJ/kg$$

EXAMPLE 1.2: A closed rigid tank contains a two-phase liquid–vapor mixture of Refrigerant 22 initially at –20°C with a quality of 50.36%. Energy transfer by heat into the tank occurs until the refrigerant is at a final pressure of 6 bar. Determine the amount of energy transfer by heat, in kJ per kg of refrigerant.

STATE 2: SUPERHEATED VAPOR

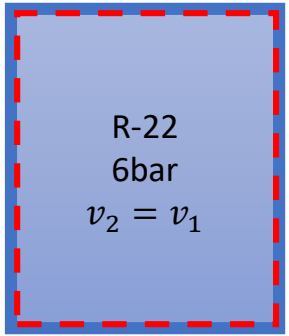


TABLE A-9

(Continued)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	$p = 5.5$ bar $= 0.55$ MPa ($T_{sat} = 3.08$°C)				$p = 6.0$ bar $= 0.60$ MPa ($T_{sat} = 5.85$°C)			
Sat.	0.04271	227.53	251.02	0.9226	0.03923	228.44	251.98	0.9186
5	0.04317	228.72	252.46	0.9278				
10	0.04433	231.81	256.20	0.9411	0.04015	231.05	255.14	0.9299
15	0.04547	234.89	259.90	0.9540	0.04122	234.18	258.91	0.9431
20	0.04658	237.95	263.57	0.9667	0.04227	237.29	262.65	0.9560
25	0.04768	241.01	267.23	0.9790	0.04330	240.39	266.37	0.9685
30	0.04875	244.07	270.88	0.9912	0.04431	243.49	270.07	0.9808
35	0.04982	247.13	274.53	1.0031	0.04530	246.58	273.76	0.9929
40	0.05086	250.20	278.17	1.0148	0.04628	249.68	277.45	1.0048
45	0.05190	253.27	281.82	1.0264	0.04724	252.78	281.13	1.0164

$P_2 = 6bar, v_2 = v_1 = 0.047\ m^3/kg$, interpolating to find temperature and internal energy

$T_2 = 43.75\ °C$

$u_2 = 252.005\ kJ/kg$

Applying the first law for closed systems:

$$\Delta U = Q - W$$

$$U_2 - U_1 = Q - W$$

Per kilogram

Replacing

$$u_2 - u_1 = q - w$$

The work is zero because there is no shaft work, and the recipient is a rigid tank (no volume change)

$$252.005 - 121.3906 = q - 0$$

$$\boldsymbol{q = 130.6144\ kJ/kg}$$

HOMEWORK: T(^{o}C)-v(m^3/kg) DIAGRAM, ALSO DRAW THE ISOBARS (kPa)

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

$$\Delta U + \Delta E_K + \Delta E_P = Q_{NET} - W_{NET}$$

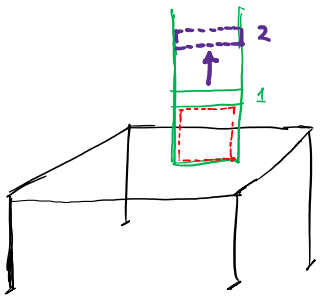
$kg \times m(u_2 - u_1)$ → $\frac{kJ}{kg}$ kJ

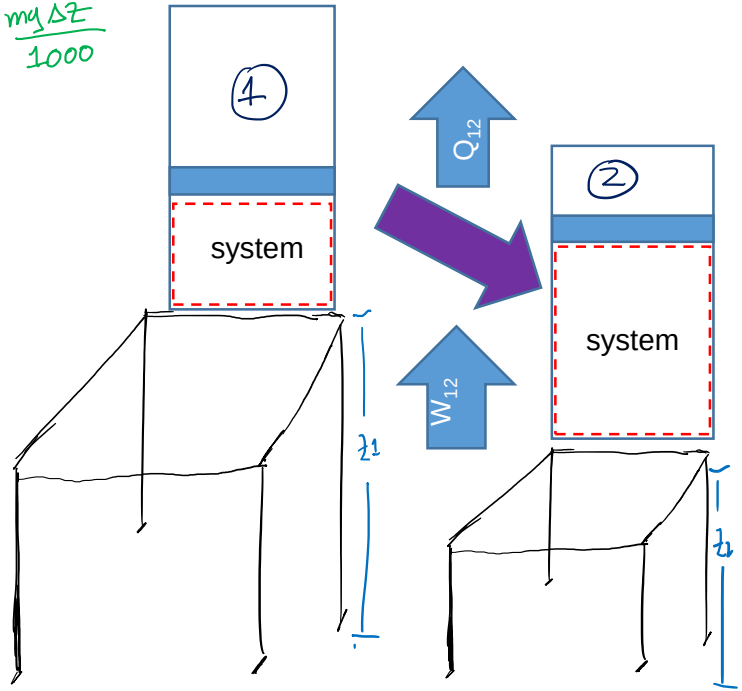
$\frac{1}{2} m v^2 \rightarrow \left[kg \cdot \frac{m^2}{s^2}\right]$ → J

$mg\Delta z \rightarrow \left[kg \frac{m^2}{s^2}\right]$ → J

$$kJ = \frac{\frac{1}{2} m v^2}{1000}$$

$$kJ = \frac{mg\Delta z}{1000}$$





EXAMPLE 4.2: A closed system of mass 10 kg undergoes a process during which there is energy transfer by work from the system of 14.7 kJ/kg, an elevation decrease of 50 m, and an increase in velocity from 15 m/s to 30 m/s. The specific internal energy decreases by 5 kJ/kg and the acceleration of gravity is constant at 9.8 m/s^2. Determine the heat transfer for the process, in kJ.

$\Delta E = Q - W$

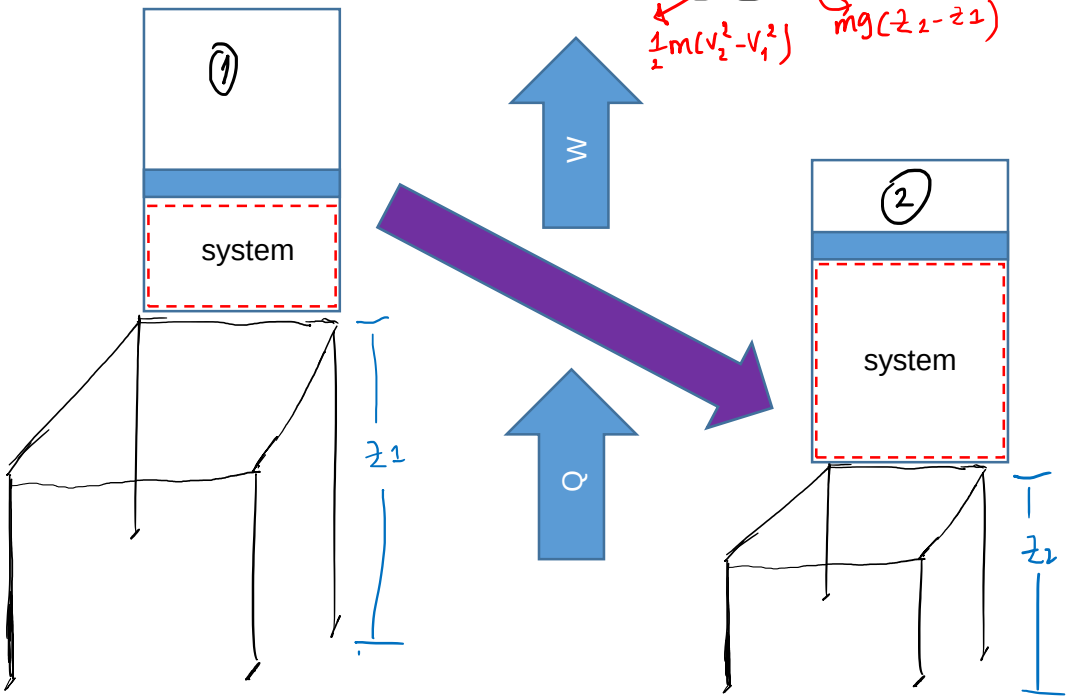
$\Delta U + \Delta E_K + \Delta E_P = Q - W$

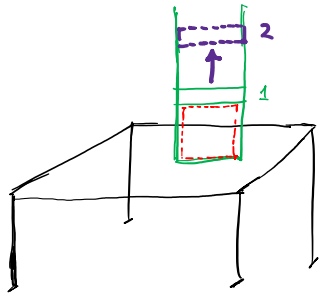
$\frac{1}{2}m(V_2^2 - V_1^2)$ $\quad mg(z_2 - z_1)$

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

$\Delta u = q - w \quad [kJ/kg]$

$m\Delta u = mq + mw \quad [kJ]$





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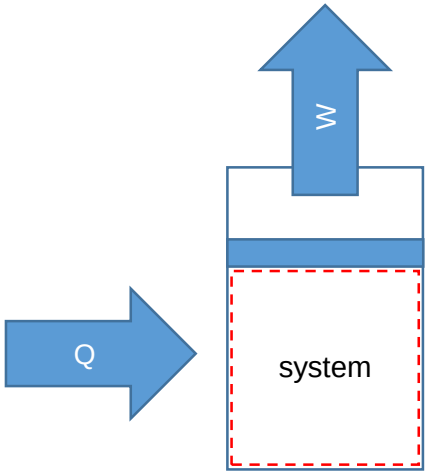

First law for closed systems:

$$E_2 - E_1 = Q - W$$

$$\left(\frac{1\ \text{kJ/kg}}{1000\ \text{m}^2/\text{s}^2}\right)$$

ΔE_K ΔP_E ΔU

$$(KE_2 - KE_1) + (PE_2 - PE_1) + (U_2 - U_1) = Q - W$$

$$\frac{1}{2}m\,(v_2^2 - v_1^2) + mg(z_2 - z_1) + m(u_2 - u_1) = Q - W$$

$$\frac{1}{2} \times 10 \times (30^2 - 15^2)/1000 + 10 \times 9.8 \times (-50)/1000 + 10 \times (-5) = Q - 10 \times 14.7$$

$$Q = 95.475 kJ$$


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Thanks!