Good morning!

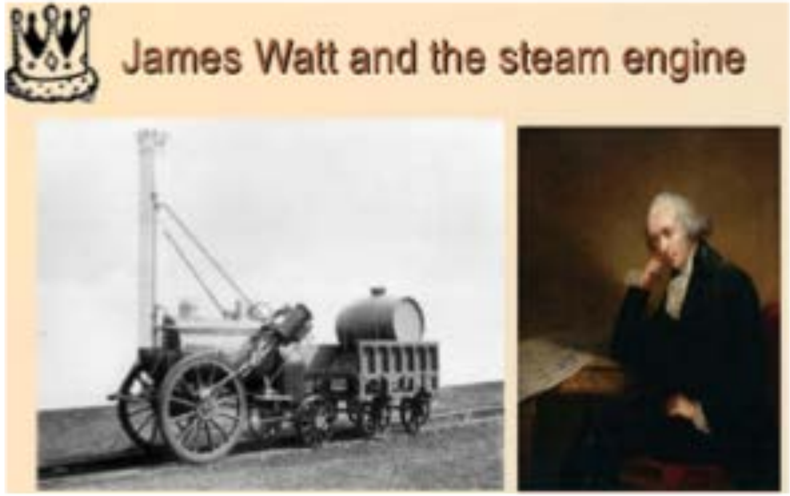
Lab 10 is in SCI136

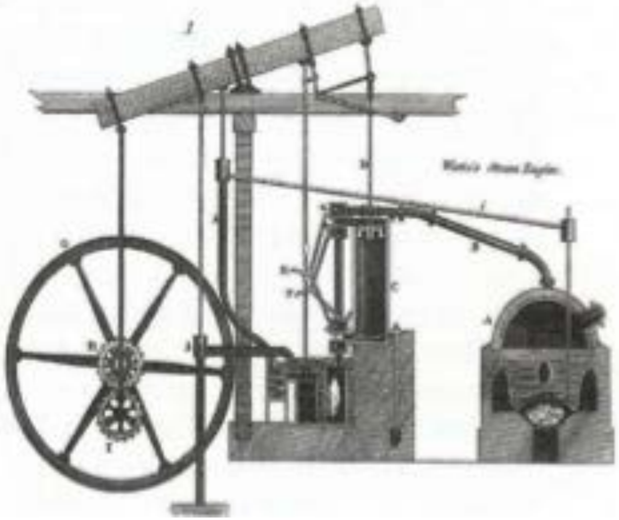
For labs 2 – 10 the best 8 scores out of 9 will be used for the final grade calculation

Lab 11a,b (webassign survey) is <u>optional</u>

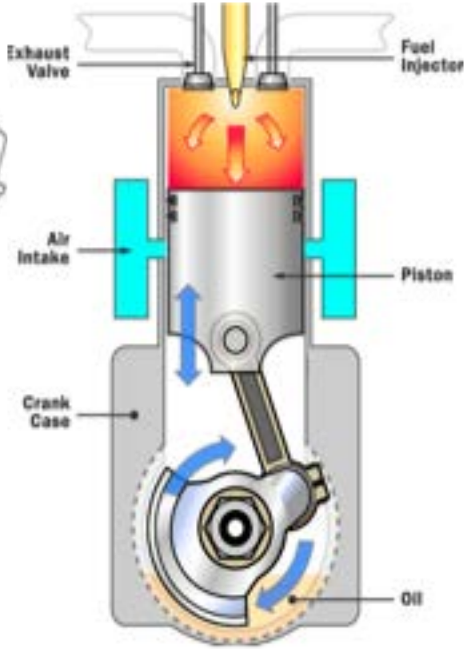
Please, login into webassing, locate LectureMCQ_L25 (PY105) and answer question 1 (but ONLY Q1!). Thank you!

Steam Engines



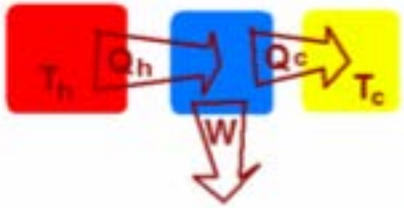


Internal Combustion Engines



A Heat Engine

The higher temperature causes the system to expand, doing work, and the lower temperature re-sets the engine so another cycle can begin.



In a full cycle of a heat engine, three things happen:

1. Heat Q_h is added at a relatively high temperature T_h.

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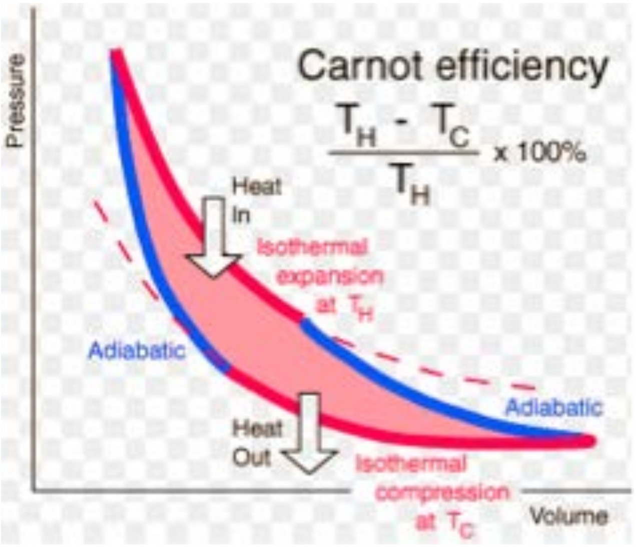


Webassign: L25_Q2

For one *complete* cycle:

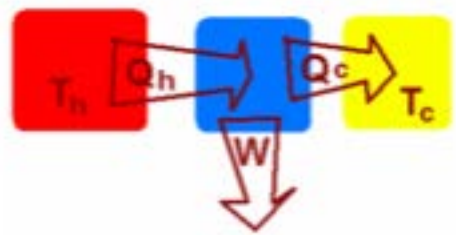
1. ΔU > 0 **2. ΔU = 0** **3. ΔU < 0**

4. It depends on the direction of the cycle

$$U = \frac{i}{2} nRT$$

A Heat Engine

The higher temperature causes the system to expand, doing work, and the lower temperature re-sets the engine so another cycle can begin.



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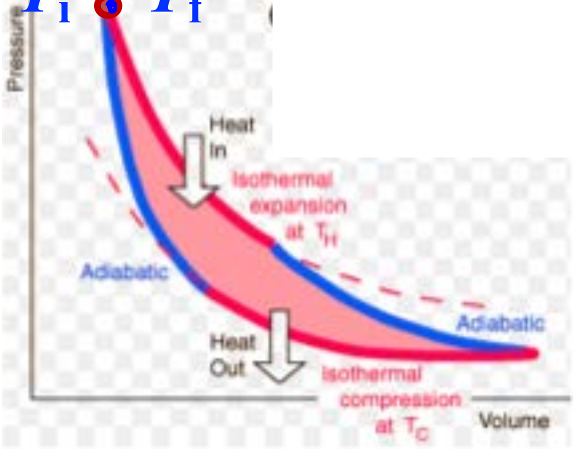
$T_i = T_f$



$$U = \frac{i}{2} nRT$$

$T_i = T_f$

$\Delta U = \frac{i}{2} nR\Delta T = \phi$

A Heat Engine

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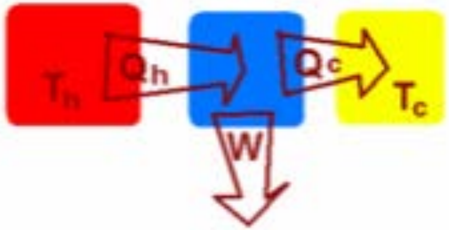

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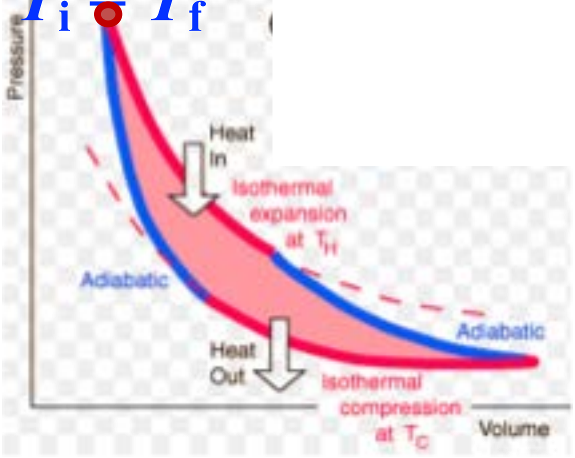


$$U = \frac{i}{2} nRT$$

$T_i = T_f$ ⇨ $U_i = U_f$

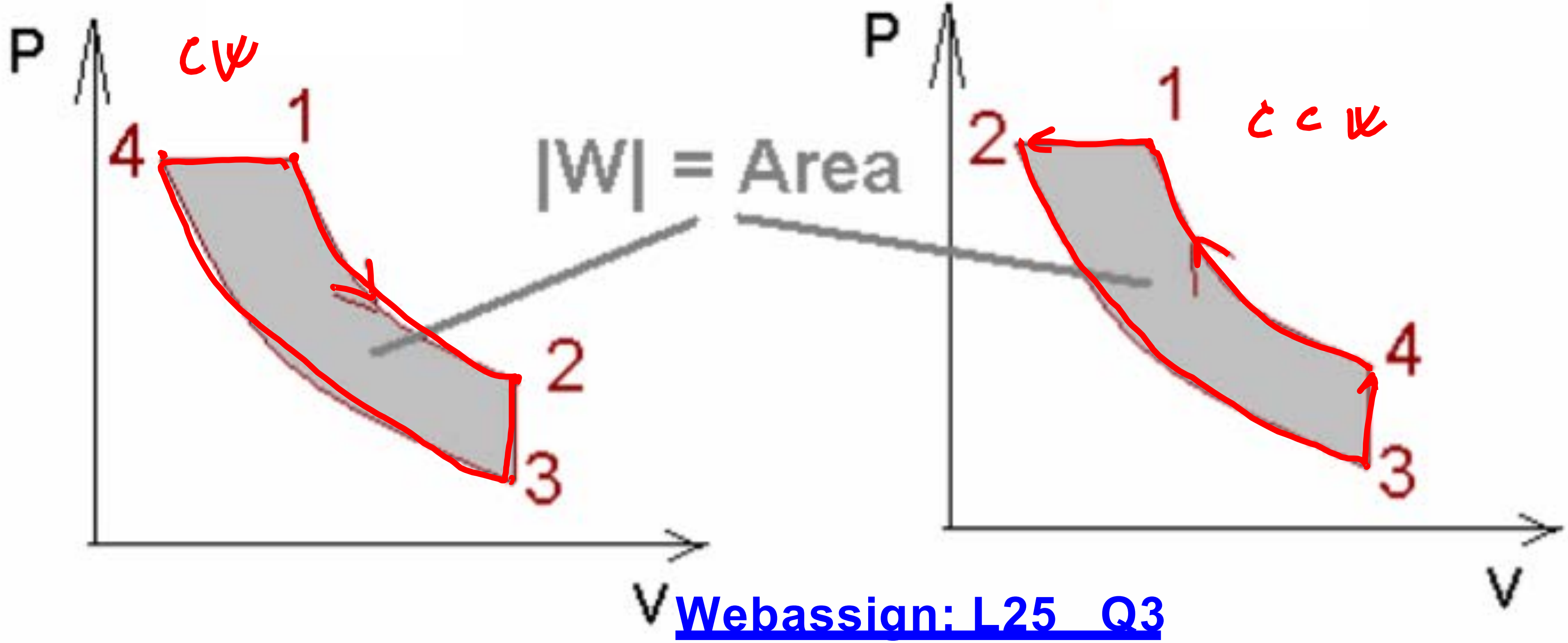
For one *complete* cycle:

1. ΔU > 0 **2. ΔU = 0** **3. ΔU < 0**

4. It depends on the direction of the cycle

0

A cyclic process



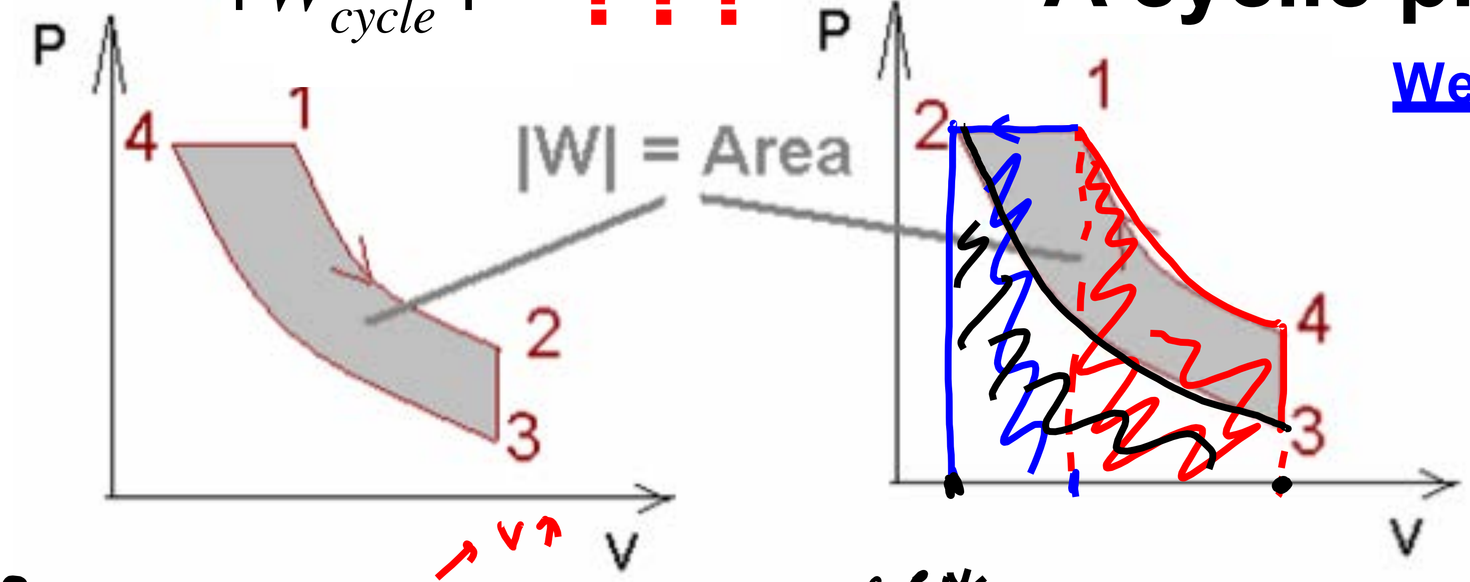
[Webassign: L25 Q3]

The work done by the gas in the cycle on the right is … 1. > 0 2. 0 3. < 0.

4. Not enough

$|W_{cycle}| = $ **???**

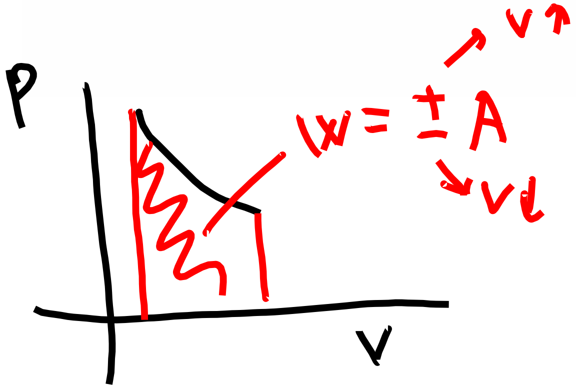
A cyclic process

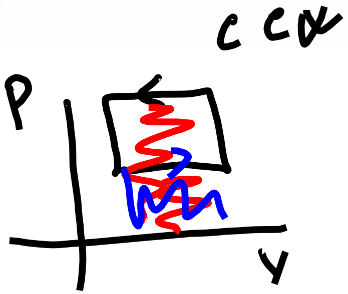


Webassign: L25_Q3

$W_{right\_cycle} =$

1. > 0
2. 0
3. < 0.
4. Not enough





$W_{3\to4} = 0$

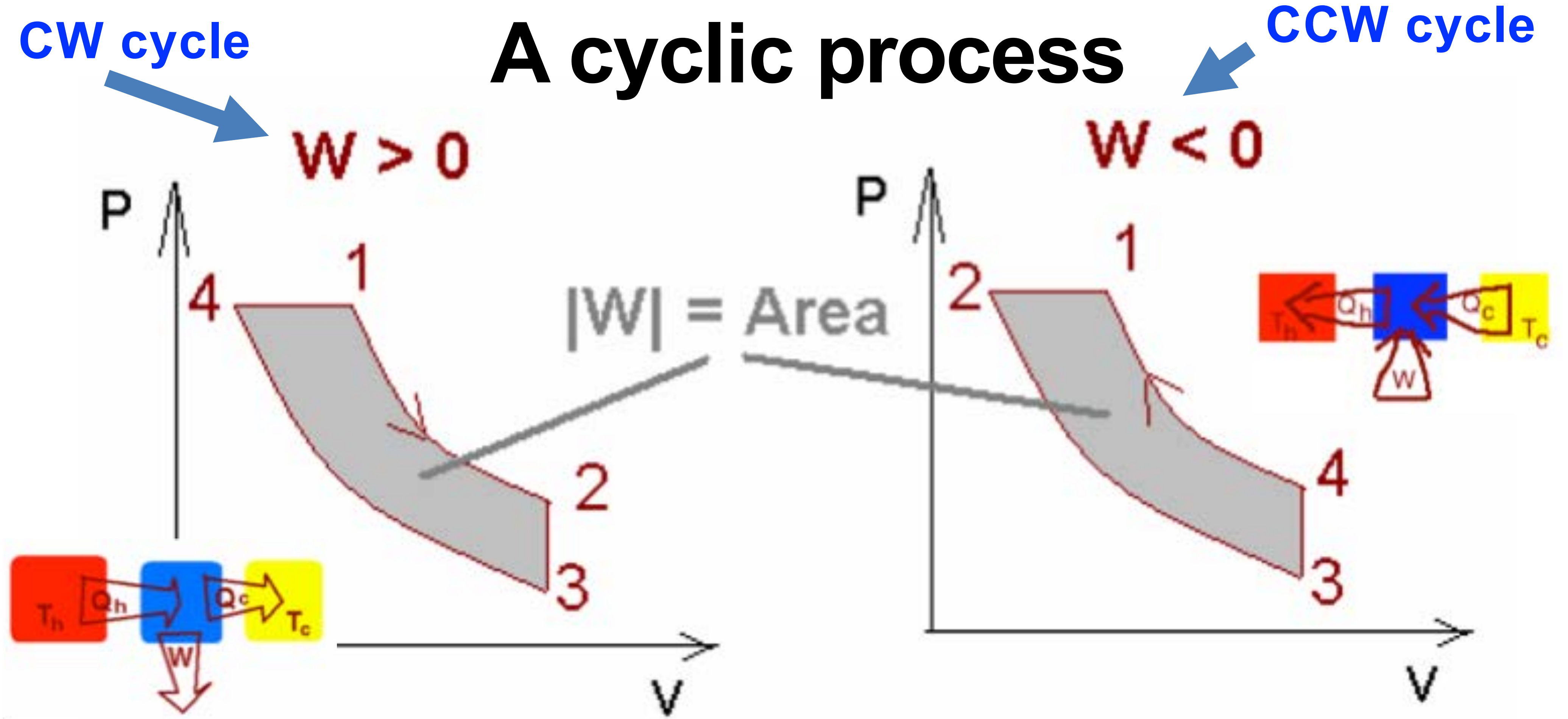
$W_{4\to1} < 0$

$W_{1\to2} < 0$

$W_{2\to3} > 0$

$W_{total} = W_c = W =$
$= -|A_{41}| - |A_{12}| +$
$+ |A_{23}| < 0$

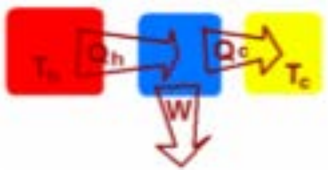
A cyclic process



$$|W_{cycle}| = Area \qquad W_{cycle} = \pm Area$$

A Heat Engine

The higher temperature causes the system to expand, doing work, and the lower temperature re-sets the engine so another cycle can begin.



In a full cycle of a heat engine, three things happen:

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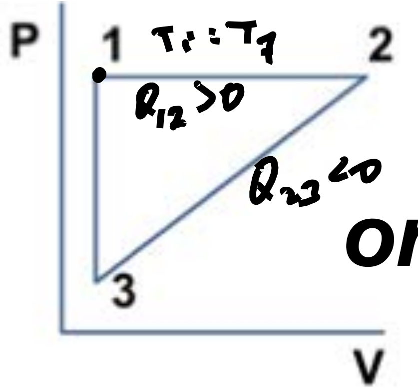
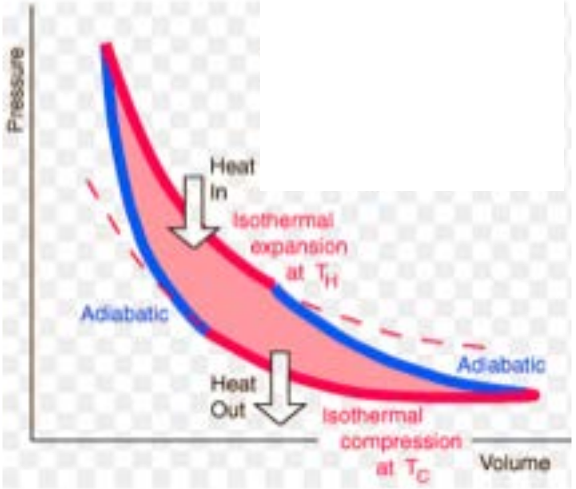
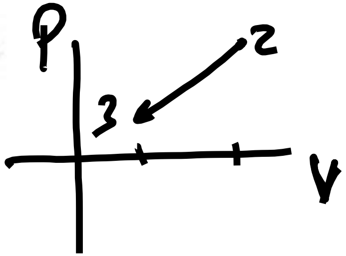


or



Any cycle

Q, ΔU, W
(1) for each process;
(2) for the cycle.



$V \downarrow \Rightarrow W < 0$

$P_2 V_2 = nRT_2 \; ; \; P_3 V_3 = nRT_3$

$P_2 > P_3 \; ; \; V_2 > V_3$

$\Downarrow$

$T_2 > T_3$

$\Delta U = \frac{i}{2} n \Delta T \downarrow \quad \Delta U < 0$

$Q = \Delta U + W < 0$

$\Delta U = 0 \; ; \; Q = \cancel{\Delta U} + W$

$Q_{ab} - |Q_{rel}| = Q_{ab} + Q_{rel} = Q = W \Rightarrow W < Q_{abs}$

A Heat Engine

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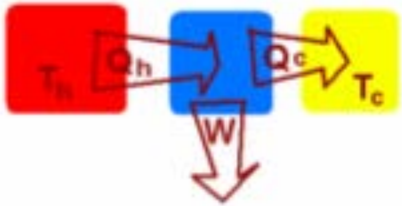

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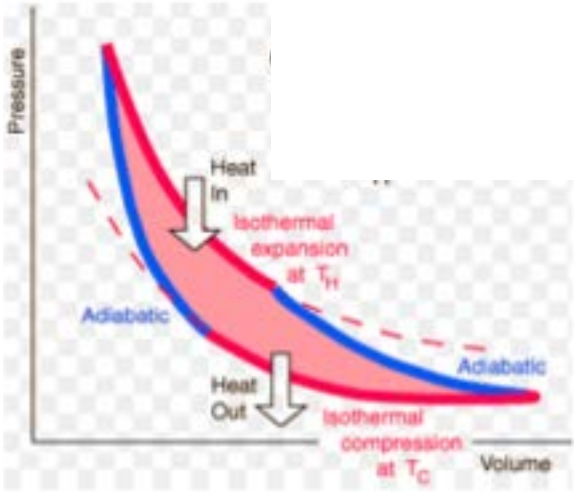
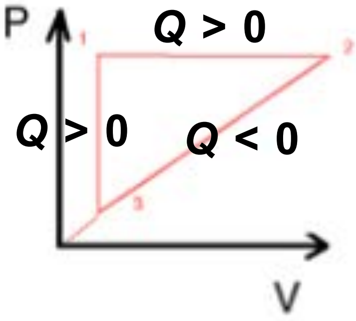


$$Q_{cycle} = \Delta U_{cycle} + W_{cycle}$$



For one complete cycle: $\Delta U_{cycle} = 0$

1) $Q_{cycle} = Q_{absorbed} + Q_{released}$

2) $Q_{cycle} = W_{cycle}$

$$Q_{absorbed} + Q_{released} = W_{cycle}$$

320 kJ of heat energy is transferred to a system consisting of 30 moles of an ideal gas.
If the pressure of this gas stays constant at 2000 kPa, and the volume increased from 40 L to 80 L.
Calculate: the change in internal energy of the gas.

320 kJ of heat energy is transferred to a system consisting of 30 moles of an ideal gas. If the pressure of this gas stays constant at 2000 kPa, and the volume increased from 40 L to 80 L. Calculate: the change in internal energy of the gas.

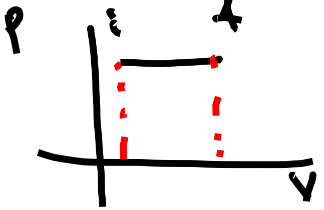
$Q = 320000\ J$

$P = 2000\ kPa$

$V_i = 40L$

$V_f = 80\ L$

$n = 30\ mol$



$W = P \cdot \Delta V = 2000\ kPa \cdot (80L - 40L) = 2000 \cdot 40 = 80000\ J$

$\Delta U = \frac{i}{2} n R \Delta T = \frac{i}{2} P \Delta V = \frac{i}{2} W = i \cdot \frac{80000}{2} = i \cdot 40000$

$i \rightarrow 3,\ 5,\ 6$ (?)

$Q \rightarrow cm\Delta t$

$Q \rightarrow \Delta U + W \Rightarrow$

$Q = \Delta U + W$

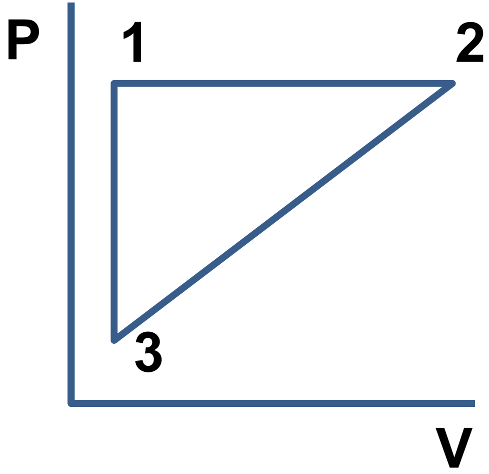
$32\cancel{0}\cancel{0}\cancel{0}\cancel{0} = i \cdot 4\cancel{0}\cancel{0}\cancel{0}\cancel{0} + 8\cancel{0}\cancel{0}\cancel{0}\cancel{0}$

$\frac{32 - 8}{4} = i$

$i = 6 \Rightarrow$

$\Delta U = 6 \cdot 40000 = 240000\ J$

320 kJ of heat energy is transferred to a system consisting of 30 moles of an ideal gas. If the pressure of this gas stays constant at 2000 kPa, and the volume increased from 40 L If this process is the first in the cycle shown in the diagram, and P_3 = 1000 kPa find; how much heat does it absorb, release, and the work done in one cycle.

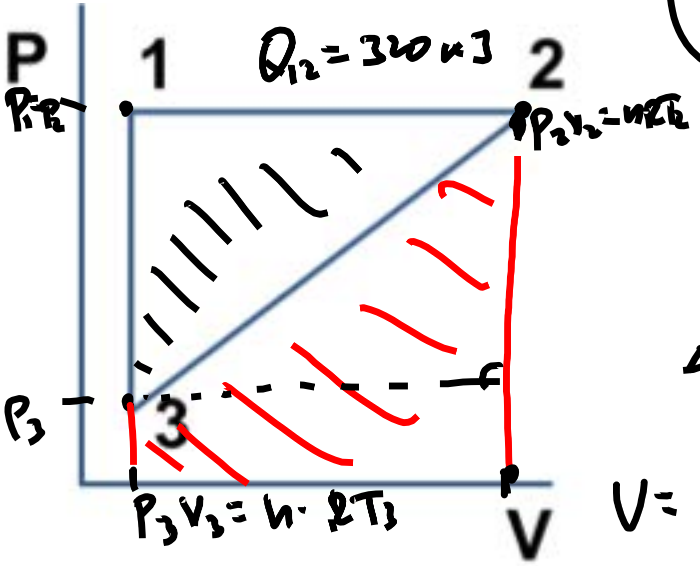


$Q_{1\text{-}2}$ = 320 kJ; n = 30 mol; P_1 = 2000 kPa, V_1 = 40 L; V_2 = 80 L
P_3 = 1000 kPa; find; how much heat does it absorb, release, and the work done in one cycle.

$\Delta U_{cycle} = 0$; $Q_{cycle} = W = \frac{1}{2} \cdot (P_1 - P_3) \cdot (V_2 - V_1) = \frac{1}{2} 1000\,kPa \cdot 40\,L =$

$= 20000\,J$

$W_{12} = 80000\,J$

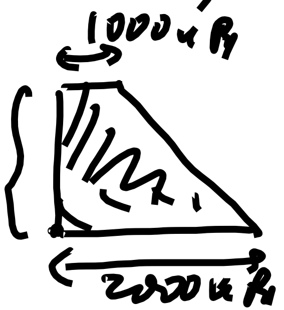


2 → 3

$Q_{23} = \Delta U_{23} + W_{23}$

$W_{23} = -\frac{1}{2} \cdot (V_2 - V_3) \cdot (P_3 + P_2) = -\frac{1}{2}\, 40\,L \cdot (1000 + 2000) =$

$= -20 \cdot 3000 = -60000\,J$



$\Delta U_{23} = \frac{6}{2}(P_3V_3 - P_2V_2) =$

$= \frac{6}{2}(1000 \cdot 40 - 2000 \cdot 80) =$

$= -3 \cdot 1000 \cdot 120 = -360000\,J$

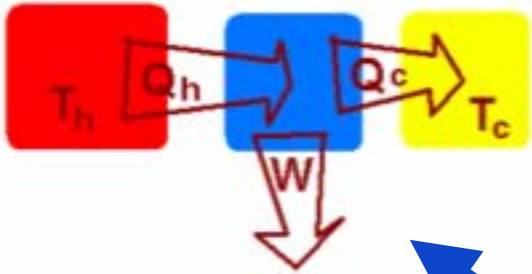
$U = \frac{i}{2} nRT = \frac{i}{2} P \cdot V$

$W_{cycle} = W$

A Heat Engine

$Q_{cycle} = Q_{absorbed} + Q_{released} = W$

The higher temperature causes the system to expand, doing work, and the lower temperature re-sets the engine so another cycle can begin.



In a full cycle of a heat engine, three things happen:

$Q_{absorbed} > 0$

1. Heat Q_h is added at a relatively high temperature T_h.

2. Some of the energy from the input heat is used to do work W.

3. The rest of the energy is removed as heat Q_c at a relatively low temperature T_c.

$Q_{released} < 0$

$Q_c = -|Q_c|$

$W = Q_h + Q_c = Q_h - |Q_c|$

The conservation of energy, for a cycle: $\boxed{Q_h = W + |Q_c|}$

Efficiency

$$Q_h = W + |Q_c|$$

The efficiency of an engine tells us how much of the input energy ends up doing useful work.

$$W = Q_h - |Q_c| < Q_h$$

ALSWAYS!

The efficiency is defined as:

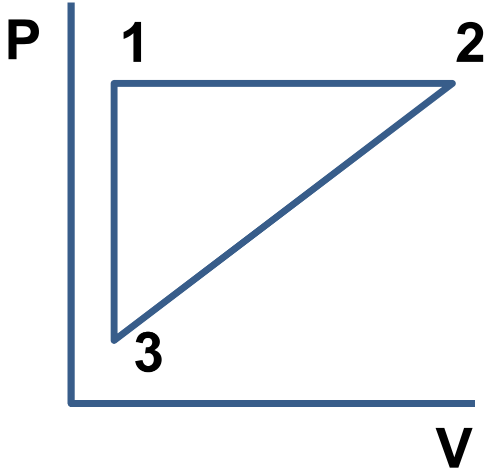
$\frac{W}{|Q_h|} \cdot 100\% = e$

$$e = \frac{W}{|Q_h|} = \frac{|Q_h| - |Q_c|}{|Q_h|} = 1 - \frac{|Q_c|}{|Q_h|}$$

For ANY engine

This is the maximum possible efficiency of an engine. In practice losses from friction and other sources reduce the efficiency.

320 kJ of heat energy is transferred to a system consisting of 30 moles of an ideal gas. If the pressure of this gas stays constant at 2000 kPa, and the volume increased from 40 L If this process is the first in the cycle shown



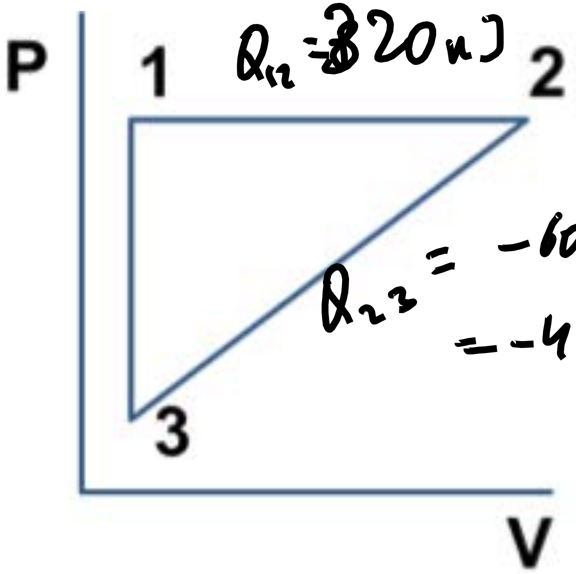
in the diagram, and P_3 = 1000 kPa find; calculate the efficiency of the engine based on this cycle.

$Q_{1\text{-}2}$ = 320 kJ; n = 30 mol; P_1 = 2000 kPa, V_1 = 40 L; V_2 = 80 L P_3 = 1000 kPa; find; calculate the efficiency of the engine based on this cycle.

$Q_h - 420000 = 20000$

$e = \frac{20000}{Q_h}$; $Q_h = 420000 + 20000 =$

$= 440000$ J



$Q_{12} = 320$ kJ

$Q_{23} = -60000 - 360000 =$

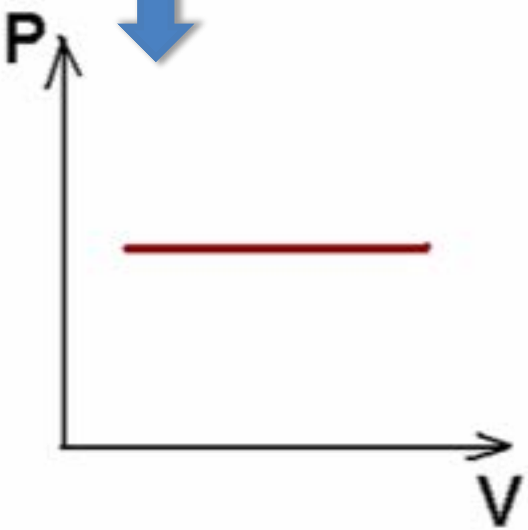
$= -420000$ J

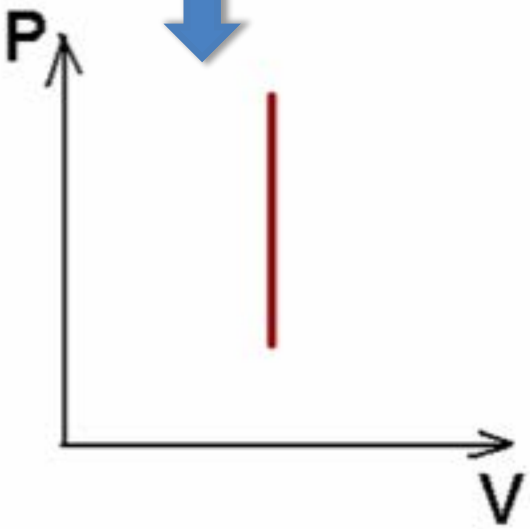
$e = \frac{20000}{440000} \cdot 100\% =$

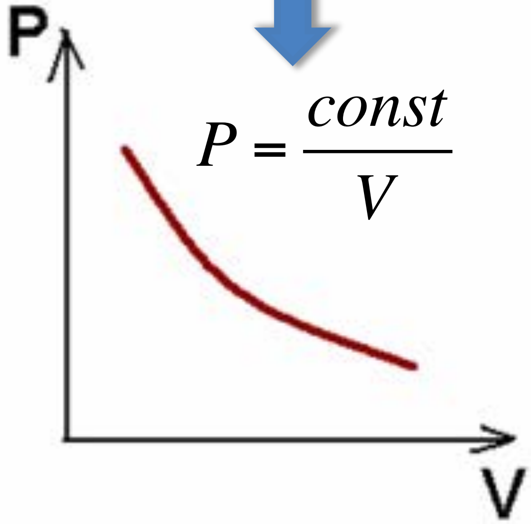
$= \frac{200}{44}\% = 4.5\%$

Three standard processes (n = const):

Isobaric	Isochoric	Isothermal
P = const	V = const	T = const
V/T = const	P/T = const	PV = const







$$P = \frac{const}{V}$$

n = m/M

n = const

$$\frac{PV}{Tn} = R$$ **= 8.31 J/(Kmole)**

(Try to plot graphs for the same processes using PT and VT axes)

Adiabatic process.

Happens without heat exchange with the surrounding

$$Q = 0 \Rightarrow \quad 0 = \Delta U + W_{byS}$$

$$\Rightarrow \Delta U = -W_{byS}$$

$$\Rightarrow \Delta U = W_{onS}$$

(1)An Insulated System

and if $W = 0$

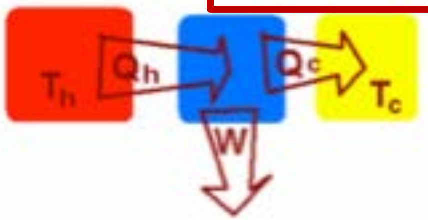
$\Rightarrow$ **U_{system} = const**

$\Rightarrow$ **$Q_1 + Q_2 + \ldots = 0$ (HBE)**

(2) A very fast process

An Ideal (Carnot) Engine

For ANY engine

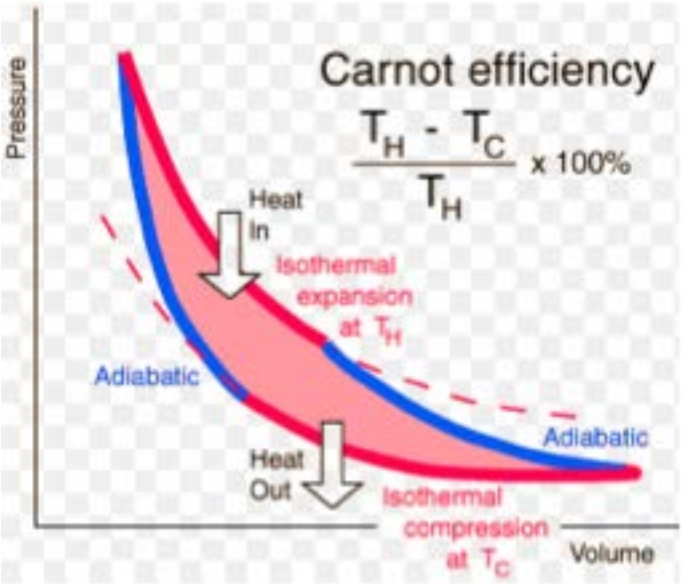


$$e = 1 - \frac{|Q_c|}{|Q_h|}$$

Carnot showed that for an *ideal* (or Carnot) engine, operating between temperatures T_h and T_c, the ***efficiency*** is:

For an ideal (a.k.a. Carnot) engine

$$e_c = 1 - \frac{T_c}{T_h}$$



Every cycle an ideal engine does 420 kJ of work while releasing 600kJ of thermal energy. If the lowest operating temperature is 27^{0}C, what is the highest temperature?

Every cycle an ideal engine does 420 kJ of work while releasing 600kJ of thermal energy. If the lowest operating temperature is 27⁰C, what is the highest temperature?

$$e = \frac{T_h - T_c}{T_h} = \frac{W}{Q_h} \Rightarrow \boxed{\frac{T_h - 300}{T_h} = \frac{420000}{1020000}}$$

$T_c = 27 + 273 = 300\,K$

$W = 420000\,J$

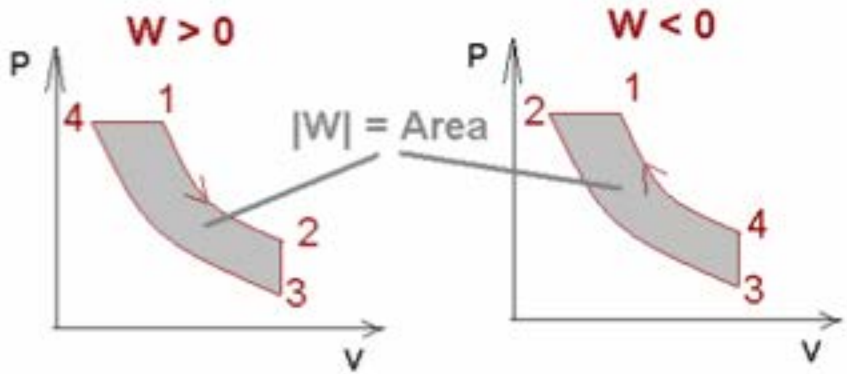
$+\ Q_c = 600000\,J$

$Q_h = 1020000\,J$

Physics is done!

In a cyclic process, the system starts in a particular state and returns to that state after undergoing a few different processes.

The net work involved is the enclosed area on the P-V diagram.



If the cycle goes clockwise, the system does work. This is the case for an engine.

If the cycle goes counter-clockwise, work is done on the system. An example of such a system is a refrigerator or air conditioner.

When the system returns to its initial state ($T_i = T_f$) there is no change in internal energy after going around the cycle $\Delta U = 0$,

Hence: $Q_{cycle} = W_{cycle}$ $= Q_h + Q_c = Q_h - |Q_c|$ => $Q_h = W + |Q_c|$

The summary:

$$e = \frac{W}{|Q_h|}$$

$$e_c = 1 - \frac{T_c}{T_h}$$

Reversible and Irreversible Processes

Let's say you rotate the "entropy jar" 10 times CCW. If you videotaped this and ran the film backwards it would be obvious to you that the film was running backwards. Why?

The process in the backward film violates:

1) **The second Newton's Law**
2) **The Law of Conservation of Energy**
3) **The Law of Conservation of Momentum**
4) **The Frist Law of thermodynamics**
5) **None of the above**
6) **All of the above**

Webassign: L25_Q4

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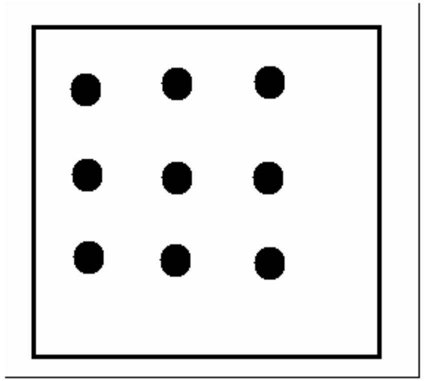
Entropy

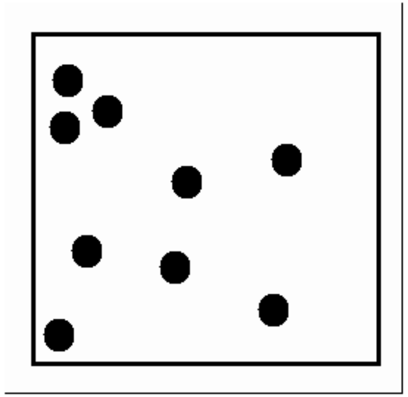
Entropy is a measure of *disorder* in a system.

Entropy is "proportional" to a chaos in the system: the more chaos => the more entropy

Order => low entropy



Chaos => high entropy



The symbol for entropy is S, and the units are J/K.

Reversible process vs. irreversible process

A *reversible* process is one in which there is *no* change in entropy, and the system *and the surroundings* can be returned to the initial state.

Irreversible process

→→

Chaotic state

Ordered state

or (slide it carefully!)

Reversible process

→→

A transition from an ordered sate to a chaotic state is *irreversible*!

The entropy of an ***isolated*** system NEVER decreases!

The Second Law of Thermodynamics (2LT)

$$\Delta S = \frac{Q}{T_{const}}$$

In *any* process the entropy of a closed system ether increases or stays the same, *it never decreases*. Hence, the change in entropy of a closed system is *never* negative!

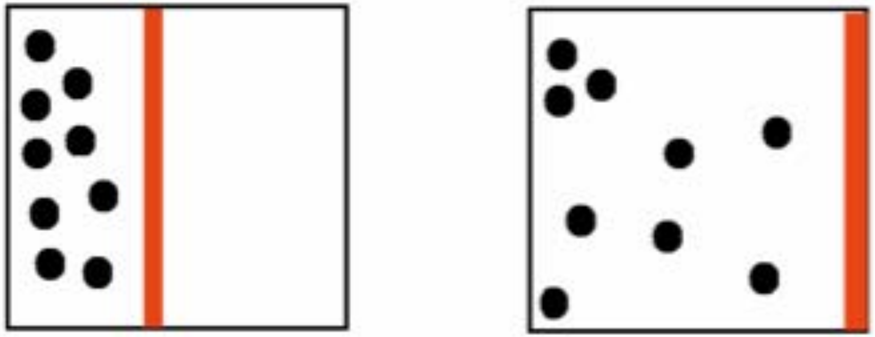
$$\Delta S \geq 0$$

When a closed system is in equilibrium, it is in the *most* chaotic (*least* ordered) state, and the entropy of the system cannot be any higher, hence stays the same: change in entropy is zero:

$$\Delta S = 0$$

For example, a gas in equilibrium has randomly and uniformly distributed particles.

When a closed system is *not* in equilibrium, it is *not* in the *most* chaotic (*least* order) state, and the system tries to reach the most chaotic state, and the entropy of the system is increasing; $S_f > S_i$; $\Delta S > 0$



For example: if we collect all the particles in one half of a container and then release them, the particles eventually fill up the whole container, and the system will reach the least ordered state.

The opposite process requires *an external force* acting on the system, in that case the system is *not* close.

The entropy of an *isolated* system NEVER decreases!

The Second Law of Thermodynamics (2LT)

In any *isolated* (closed) system the order never increases; hence either the order remains the same or it decreases, meaning the disorder, or *chaos* increases.

5) Only the Second Law of Thermodynamics would be violated - this is why entropy is sometimes called time's arrow.

Time moves in the direction of increasing entropy (in a physical world).

These are examples of an irreversible process.
In all the examples the transition from an order to a chaos is happening.

A).  →→ 

B). A process is irreversible if *energy is lost to friction*, or

C). if energy is lost as *heat flows from a hot region to a cooler region.*

Reversible and Irreversible Processes

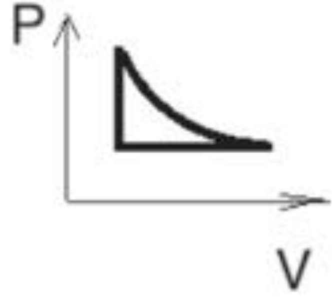
Let's say you rotate the entropy jar 10 times CCW. If you videotaped this and ran the film backwards it would be obvious to you that the film was running backwards. Why?

The process in the backward film violates:

1) **The second Newton's Law**
2) **The Law of Conservation of Energy**
3) **The Law of Conservation of Momentum**
4) **The first law of thermodynamics**
5) **The second law of thermodynamics**

Learning is irreversible!

Temperature, heat, gas: $T_k = T_c + 273$



$Q = cm\Delta T$ $Q = \pm mL$ $\sum Q = 0$

$\frac{N}{N_A} = \frac{m}{\mu} = n$ $PV = NkT = nRT$ $E_{k\,av} = \frac{i}{2}kT$

$R = kN_A$ $U = \frac{i}{2}kNT = \frac{i}{2}nRT$ $i = 3,5,6.$

W = Area($P_{vs.}$V) V↑ => W >0 V↓ => W <0

$\frac{PV}{nT} = R = const$ => $n = \text{const}$ => $\frac{PV}{T} = nR = const$ => $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$Q = W + \Delta U$ $\Delta U_{cycle} = 0$ $Q_{cycle} = W_{cycle}$

P = const: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $W = P\Delta V = nR\Delta T$ $\Delta U = \frac{i}{2}nR\Delta T$ $Q = \frac{i+2}{2}nR\Delta T$

V = const => $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ W =0 $\Delta U = \frac{i}{2}nR\Delta T$ $Q = \Delta U = \frac{i}{2}nR\Delta T$

T = const => $P_1V_1 = P_2V_2$ $Q = W$ $\Delta U = 0$

LectureMCQ_L25 Question 5

On a scale from 1 (strongly disagree) to 9 (strongly agree) how would you assess the following statement?

"I am very good at physics!"

or select 0 if you are not sure.

"I am very good at physics"

1. Strongly disagree (meaning, "I am very bad at physics")
2.
3.
4.
5. More or less agree (meaning, "I'm OK")
6.
7.
8.
9. Strongly agree (meaning, "I am very good at physics")

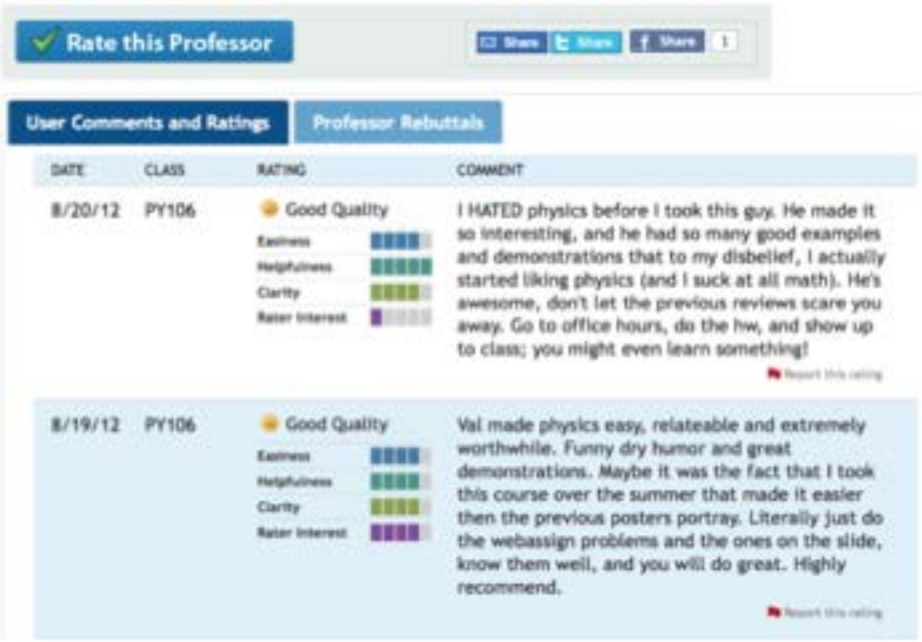
The first lecture

Response	Percent	Count
1 Strongly disagree (meaning, "I am very bad at physics")	5.33%	4
2	6.67%	5
3	10.7%	8
4	9.33%	7
5 More or less agree (meaning, "I'm OK")	26.7%	20
6	10.7%	8
7	4.00%	3
8	1.33%	1
9 Strongly agree (meaning, "I am very good at physics")	2.67%	2
0 not sure what to say	22.7%	17

The last lecture

Response	Percent	Count
1 Strongly disagree (meaning, "I am very bad at physics")	4.17%	3
2	2.78%	2
3	4.17%	3
4	4.17%	3
5 More or less agree (meaning, "I'm OK")	36.1%	26
6	12.5%	9
7	18.1%	13
8	5.56%	4
9 Strongly agree (meaning, "I am very good at physics")	4.17%	3
0 not sure what to say	8.33%	6

V.



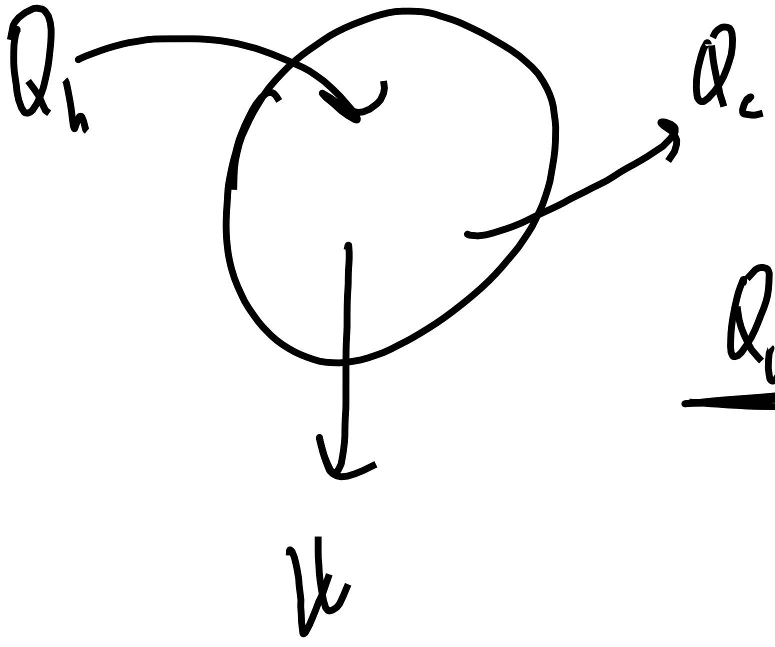
1. For only 2 people!
2. Does not provide any information to potential students.

1. For everyone!
2. Give potential students specific advices.

The END! ☹

B50

Q & A



$$Q_h - |Q_c| = W$$

HW3 PG #3:

$T_1 = t_1 + 273.15$

$T_2 = t_2 + 273.15$

$\Delta T = T_2 - T_1 =$

$= (t_2 + \cancel{273.15}) - (t_1 + \cancel{273.15})$

$W_{on} = 303 J \rightarrow W_{by} = -303 J = \Delta t$

$Q = \Delta U + W_{by}$

$\Delta U = \frac{i}{2} nR \Delta T = \frac{i}{2} \Delta (PV)$

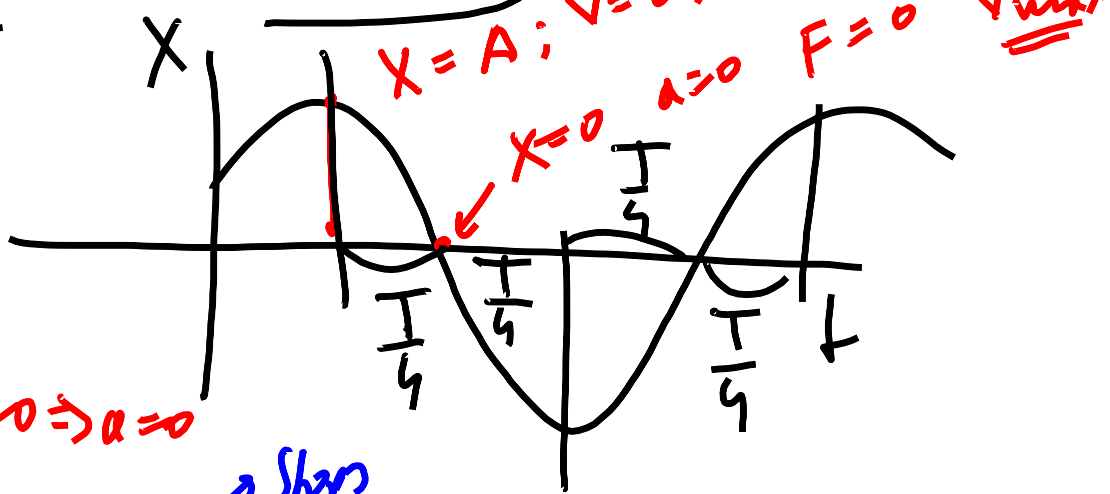
$n = 8.8$

$\Delta T = 145 - 22$

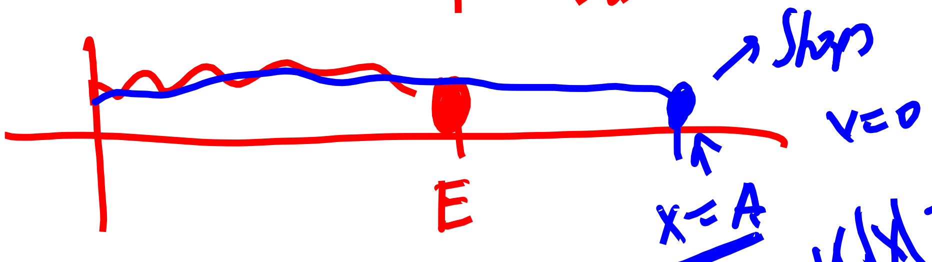
$i = 3$

HW3 P1: #7

SHM:

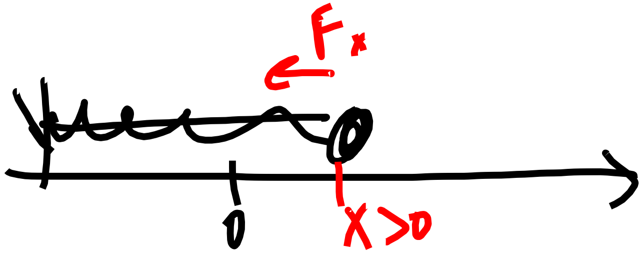


F = 0 ⇒ a = 0



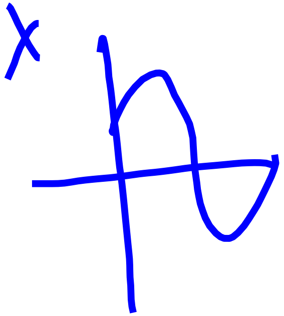
$|F| = k|x| = k \cdot A$

$|a| = \omega^2 \cdot A$

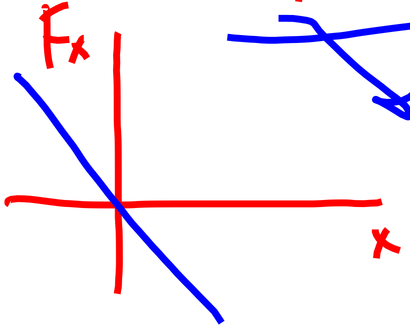


N 2c

$$|F_x| = k \cdot |x|$$



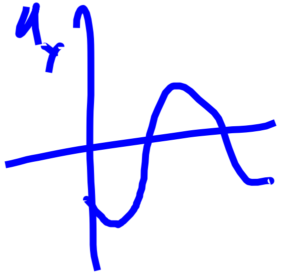
$$F_x = -k \cdot x$$



$$F_x = m a_x$$

$$m a_x = -k x$$

$$a_x = -\frac{k}{m} \cdot x$$



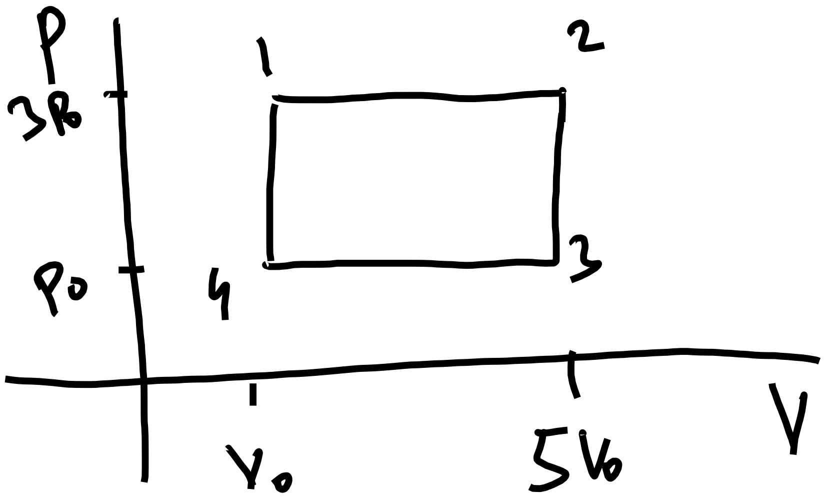
$$X = A \cdot \cos(\omega \cdot t)$$

$$[\omega] = \frac{rad}{s}$$

$$V_m = A \cdot \omega$$

$$a_m = A \cdot \omega^2 = V_m \cdot \omega$$

calculator → $\underline{\underline{rad}}$



$P_0V_0 = 1000\,J$

$C_v = \frac{3}{2}R \Rightarrow i = 3$

$1 \to 2$: $\Delta U = \frac{i}{2} nR\Delta T = \frac{i}{2} P\Delta V =$

$= \frac{3}{2} 3P_0 \cdot (5V_0 - V_0) = \frac{9}{2} \cdot 4 \cdot P_0V_0 =$

$= 18000\,J$

$\Delta U_{23} = \frac{i}{2}\Delta(P \cdot V) =$

$= \frac{3}{2} 5V_0 \cdot (P_0 - 3P_0) = \frac{3}{2} 5 \cdot (-2)\, V_0P_0$