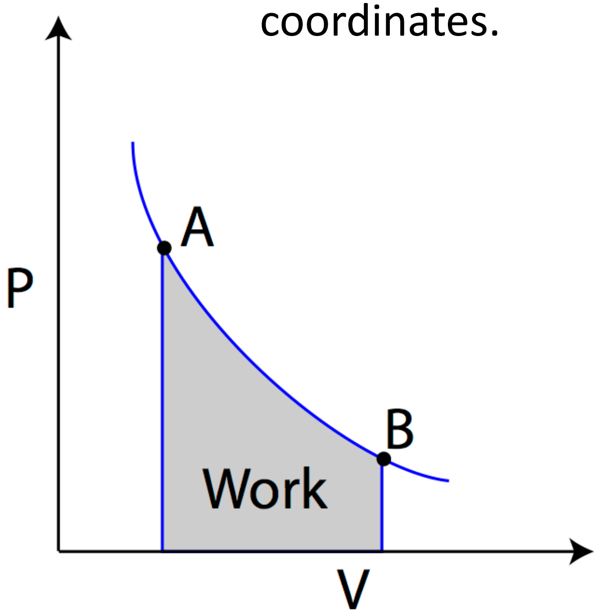
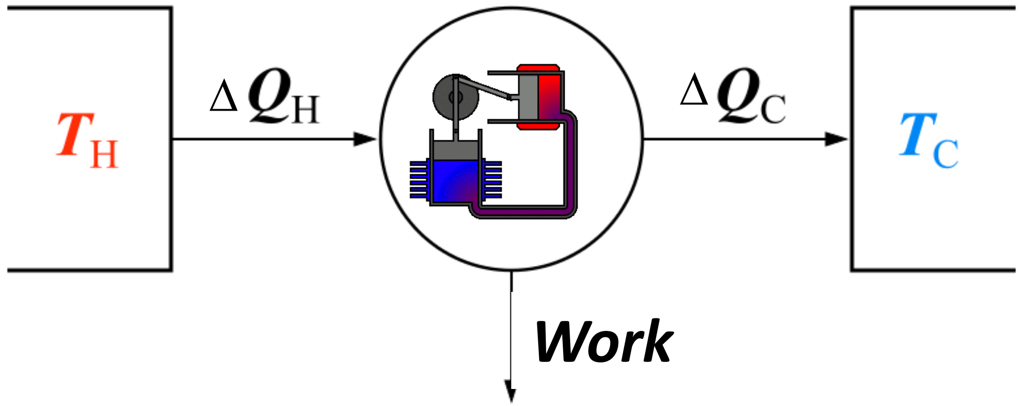
Applying the 1st Law of Thermodynamics to ideal gas

$$\Delta Q = \Delta E + \Delta W$$

- ΔQ - total heat adsorbed by gas
- ΔE – change in internal energy, $\Delta E = \mathrm{n}C_V\Delta T$. Here C_V is specific heat per mole at constant volume.
- Work ΔW can be found as an integral $\int PdV$, or area under P(V) plot coordinates.



Efficiency of Heat Engine



Heat Engine has to take heat ΔQ_H from "heat bath", and return heat ΔQ_C to a "cooler".

$$Work = \Delta Q_H - \Delta Q_C$$

Efficiency of a heat engine is $\frac{Work}{\Delta Q_H} = \frac{\Delta Q_H - \Delta Q_C}{\Delta Q_H} = 1 - \frac{\Delta Q_C}{\Delta Q_H}$

Perpetual motion

• **<u>First kind:</u> Motion with no energy source.** Impossible because of energy conservation (***The First Law of Thermodynamics***).

• **<u>Second kind:</u> converting the heat of an environment to work.**

NOPE!

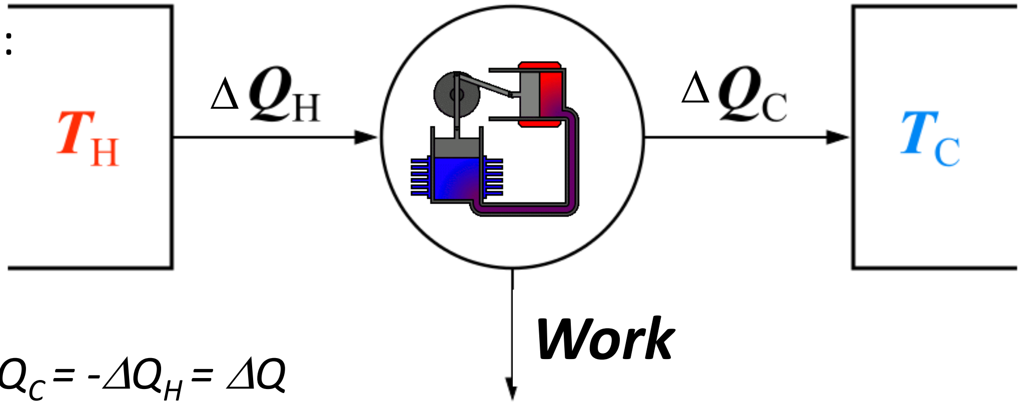
"It is impossible to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects."

Lord Kelvin's version of *the Second Law of Thermodynamics*

Second Law of Thermodynamics and Entropy

Change in entropy (Clausius definition):

$$\boxed{\Delta S = \frac{\Delta Q}{T}}$$



If *Work=0* , $\Delta Q_C = -\Delta Q_H = \Delta Q$

$$\Delta S_{total} = \frac{\Delta Q_C}{T_C} - \frac{\Delta Q_H}{T_H} = \Delta Q\left(\frac{1}{T_C} - \frac{1}{T_H}\right) \geq 0$$

Clausius version of ***the Second Law :***
"In an isolated system, the total **entropy** cannot decrease over time"

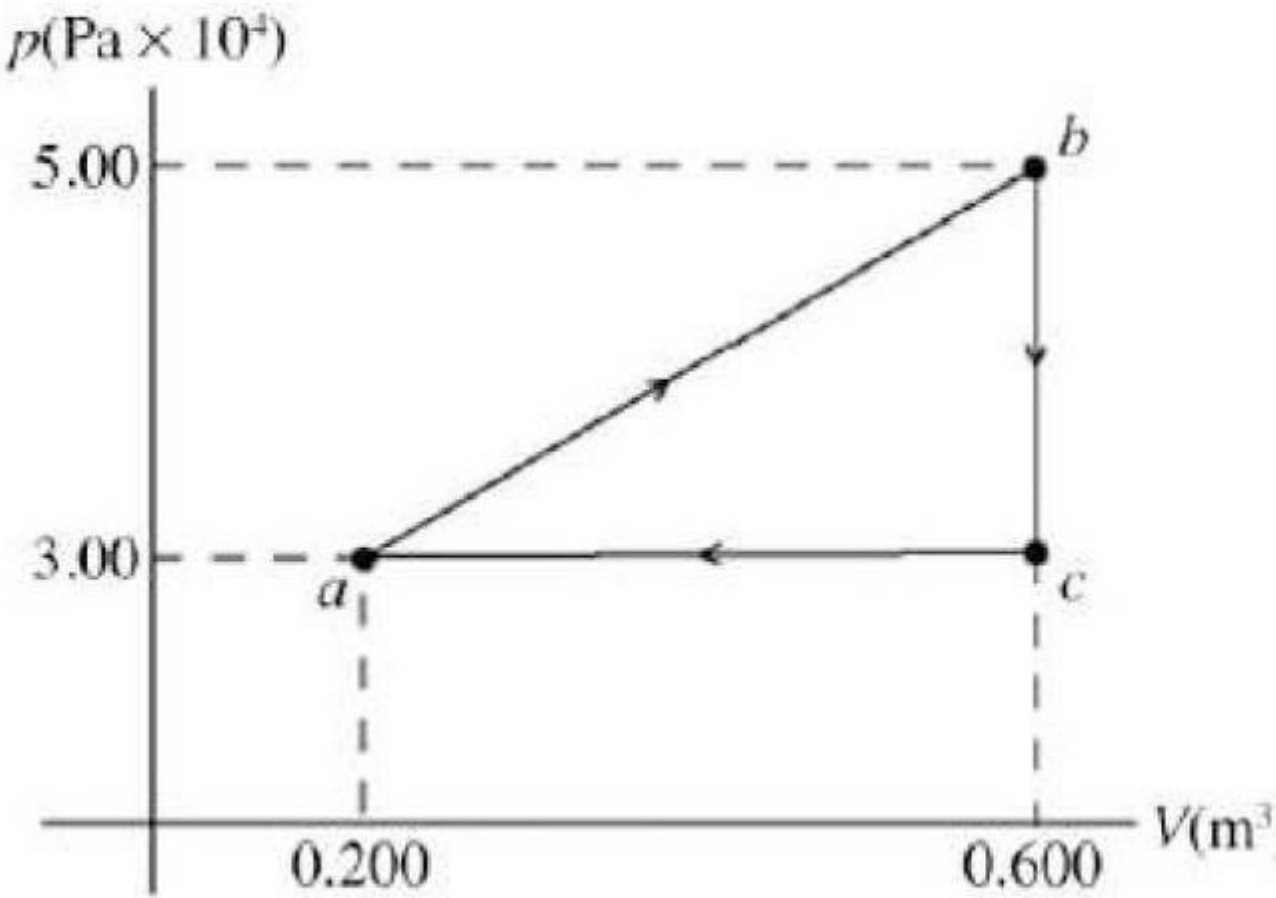
$$\Delta S_{total} = \Delta Q_H\left(\frac{1}{T_C} - \frac{1}{T_H}\right) - \frac{Work}{T_C} \geq 0$$

$Work \leq \Delta Q_H\left(\frac{T_H - T_C}{T_H}\right)$, so the maximum efficiency of a heat engine is $\frac{\Delta T}{T_{max}}$

Homework

A heat engine is using 1 mole of gas that undergoes the process shown on PV diagram. Find the change in internal energy , work done by the gas, and total heat adsorbed during each segment (a->b,b->c, and c->d). What is efficiency of this overall process? Specific heat of the gas at constant volume is C_V =20 J/K/mol. Note that PV=RT for n=1 mole. Universal gas vconstant is R= 8.3 J/K/mol

	Δ E, J	Δ W, J	Δ Q,J
a->b			
b->c			
c->a			



Problem 2. In order to achieve the maximum efficiency of a steam engine, the gas would have to follow the so-called Carnot cycle (see its PV diagram above). It consists of two isothermal processes (*T=const*), and two adiabatic ones. Adiabatic process is a fast compression or expansion ***without heat exchange***. During the adiabatic process, pressure and temperature are related as $T = const \cdot P^{1/4}$. Based on this information, find the efficiency of this steam engine, which for the Carnot cycle is $\frac{\Delta T}{T_{max}}$.

Assume that during adiabatic compression (process 4) the pressure goes up from 1 atm to the maximum that the engine can hold (16 atm).