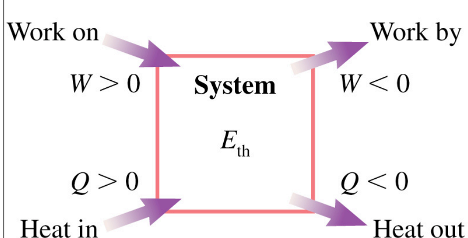
# First Law of Thermodynamics

Ferrari F430

# First Law of Thermodynamics




$$\Delta E_{th} = W + Q$$

Thermal energy $E_{th}$ : Microscopic energy of moving molecules and stretched molecular bonds. $\Delta E_{th}$ depends on the initial and final states but is independent of the process.

Work W : Energy transferred to the system by forces in a mechanical interaction.

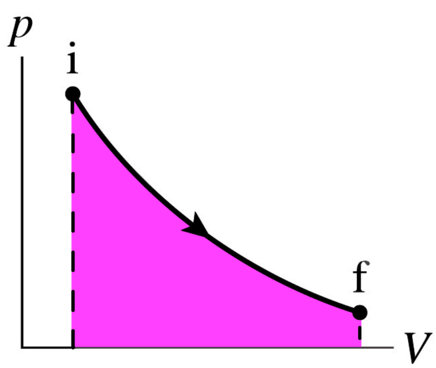
Heat Q : Energy transferred to the system via atomic-level collisions when there is a temperature difference. A thermal interaction.

Work W and heat Q depend on the process by which the system is changed.

The change of energy in the system, $\Delta E_{th}$ depends only on the total energy exchanged W+Q, *not* on the process.

# First Law of Thermodynamics

Work W done on a gas is $W = -\int_{V_i}^{V_f} p dV = -$ (area under the pV curve)



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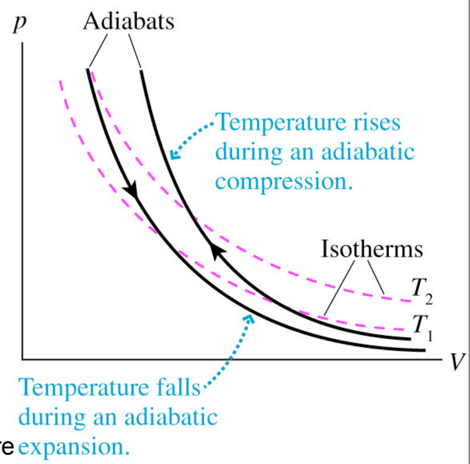
# First Law of Thermodynamics

An adiabatic process is one for which Q = 0. **Fast process but still quasi-static!** Gases move along an adiabat for which

$$pV^{\gamma} = const$$

$$\gamma = \frac{C_P}{C_V}$$




$C_V$ = molar specific heat at constant volume
$C_P$ = molar specific heat at constant pressure
$C_P = C_V + R$, universal gas constant



**An adiabatic process changes the temperature of the gas without heating it.**

A steam engine and a Ferrari P 4/5 Pininfarina: both use thermodynamic cycles to do work

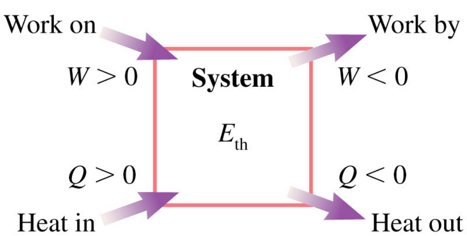
# First Law of Thermodynamics

A thermodynamic cycle

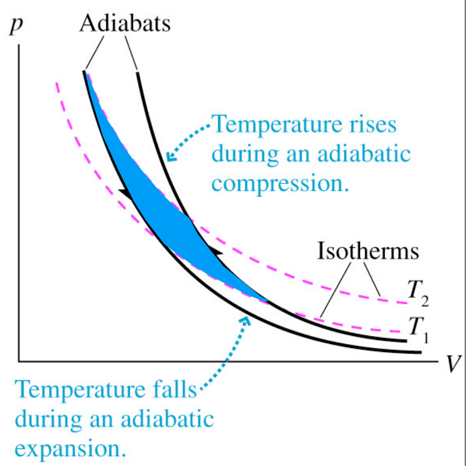
W = - (area under each pV curve)

$W_{cycle}$ = area shaded in turquoise

Pay attention to the sign of the work!





## Latent heat and specific heat

Latent heat of transformation L is the energy required for 1 kg of substance to udnergo a phase change.

$$Q = \pm ML$$

Specific heat c of a substance is the energy required to raise the temperature of 1 kg by 1 K.

$$Q = Mc\Delta T$$

Molar specific heat C of a substance is the energy required to raise the temperature of 1 mol by 1 K.

$$Q = nC\Delta T$$

If there is a phase transition involved, the heat transferred is $Q = \pm ML + Mc\Delta T = M(c\Delta T \pm L)$

The molar specific heat of gasses depends on the process by which T is changed

$C_V$= molar specific heat at constant volume

$C_p$= molar specific heat at constant pressure

$C_p = C_V + R$ (R is the universal gas constant)

$$\frac{C_p}{C_V} = \gamma$$

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## heat versus temperature

The specific heat of aluminum (Al) is about twice that of iron (Fe). Consider two blocks of equal mass, one made of aluminum and the other one made of iron, initially in thermal equilibrium.

Heat is added to each block at the same constant rate until it reaches a temperature of 500 K. Which of the following statements is true?

- The iron takes less time than the aluminum to reach the final temperature.
- The aluminum takes less time than the iron to reach the final temperature.
- The two blocks take the same amount of time to reach the final temperature.

When the two materials have reached thermal equilibrium, the block of aluminum is cut in half and equal quantities of heat are added to the iron block and to each portion of the aluminum block. Which of the following statements is true?

- The three blocks are no longer in thermal equilibrium; the iron block is warmer.
- The three blocks are no longer in thermal equilibrium; both the aluminum blocks are warmer.
- The blocks remain in thermal equilibrium.

# Steam versus hot water burns

Most people were at least once burned by hot water or steam. This problem compares the heat input to your skin from steam as opposed to hot water at the same temperature.

Assume that water and steam, initially at 100°C, are cooled down to skin temperature, 37°C, when they come in contact with your skin. Assume that the steam condenses extremely fast, and that the specific heat c = 4190 J/kgK is constant for both liquid water and steam.

Under these conditions, which of the following statements is true?

- Steam burns the skin worse than hot water because the thermal conductivity of steam is much higher than that of liquid water.
- Steam burns the skin worse than hot water because the latent heat of vaporization is released as well.
- Hot water burns the skin worse than steam because the thermal conductivity of hot water is much higher than that of steam.
- Hot water and steam both burn skin about equally badly.

# Steam versus hot water burns

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Under these conditions, which of the following statements is true?

- Steam burns the skin worse than hot water because the latent heat of vaporization is released as well.

How much heat $H_1$ is transferred to the skin by 25.0 g of steam?
The latent heat of vaporization for steam is L = 2256 kJ/kg.

- $H_1$ = 63.1 kJ

How much heat $H_2$ is transferred to the skin by 25.0 g of water?

- $H_2$ = 6.7 kJ