# Pression et température

LHC

$P = 10^{-13}$ bar

Atmosphère terrestre

B.Pascal

1623-1662

P = 1 bar

Enclumes

$P = 10^{7}$ bar

Atomes froids

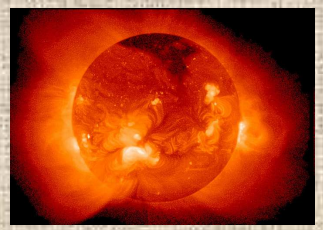
$T = 10^{-9}$ K

Galilée

1564-1642

T = 300 K

Soleil



$T = 10^{7}$ K

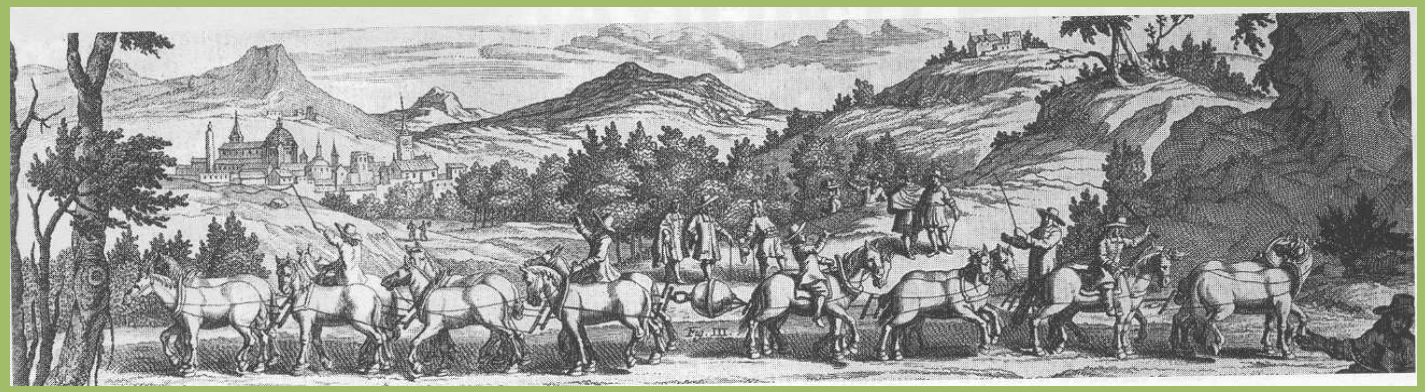
# A Magdebourg

## La nature a - t - elle horreur du vide ?

**Otto Von Guericke**

**1602-1686**

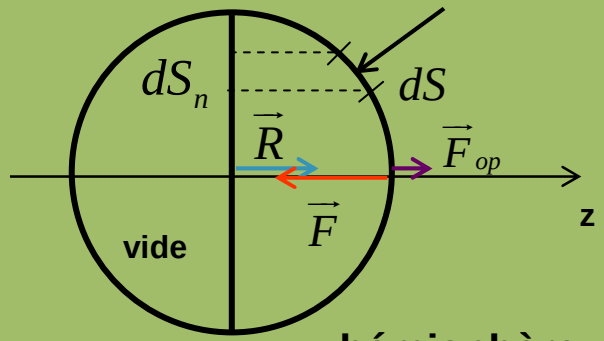
**Pompe à vide**



# Et à Lyon ?

**Hémisphères de démonstration**

$$\overrightarrow{dF} = -P\vec{n}dS$$

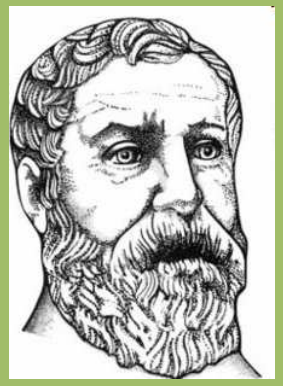



**hémisphère**

$$dF_z = -PdS_n$$

$$F_z = -P\pi R^2$$

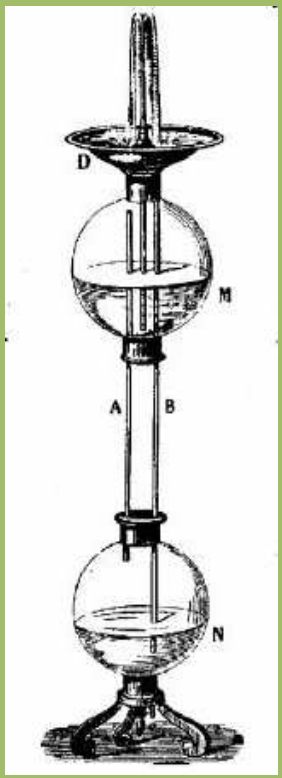
# La fontaine de Héron

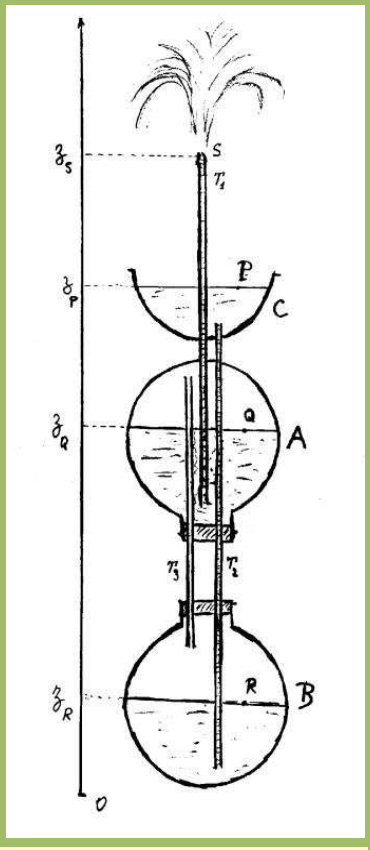


**Héron d'Alexandrie**

**(1er siècle)**

$$\Delta P = \rho g h$$

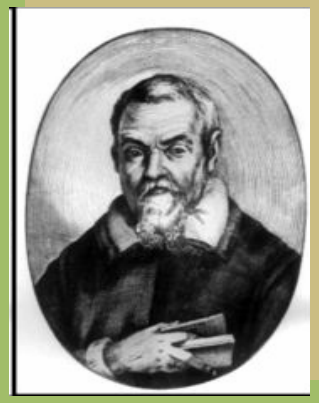



$$z_S - z_P < z_Q - z_R$$

# En Italie

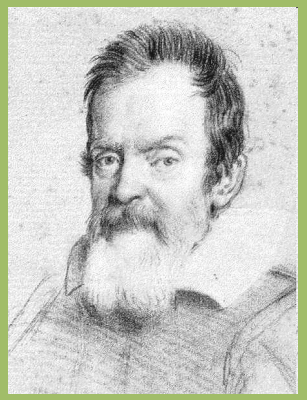
## Dilatation thermique des liquides



**Santorio de Padoue**

**1561-1636**

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$

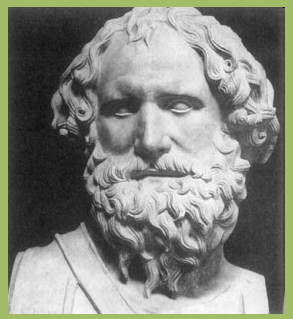


**Galilée**

**1564-1642**

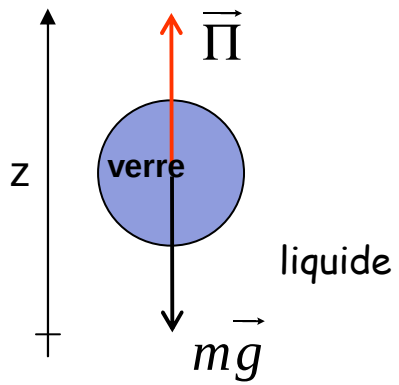
# Et à Lyon …

**Thermomètre de « Galilée »**



Archimède

$$\Pi = \rho_L V g$$



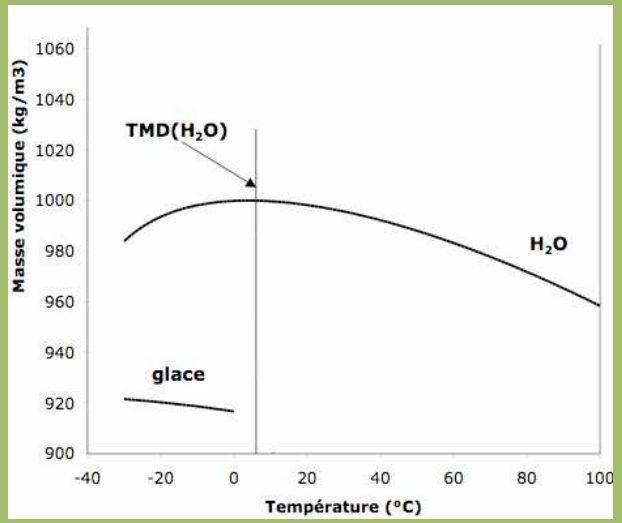

$$\alpha_L \approx 10^{-3}\ \mathrm{K}^{-1}$$

$$\alpha_{verre} \approx 10^{-5}\ \mathrm{K}^{-1}$$

$$S = \frac{dz}{dT} \approx 10^{2}\ \mathrm{m.K}^{-1}$$

# L'appareil de Hope

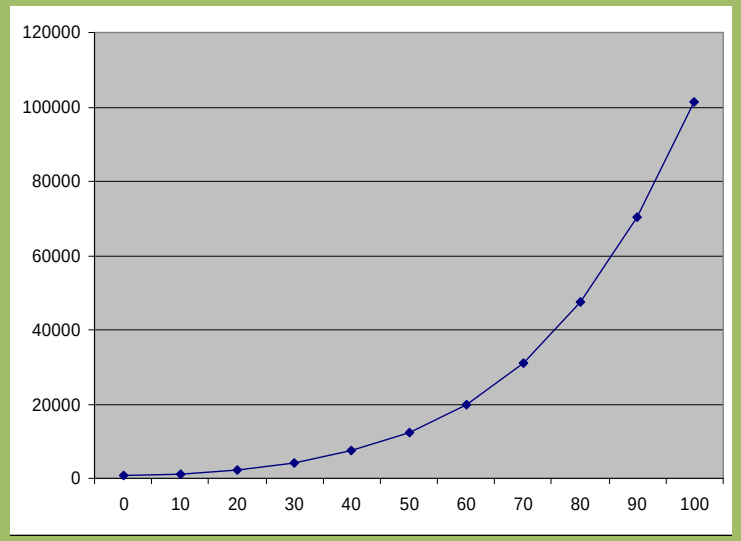
## L'eau et ses curiosités …



Appareil de Hope

# Avec P et T
# « big crunch » !

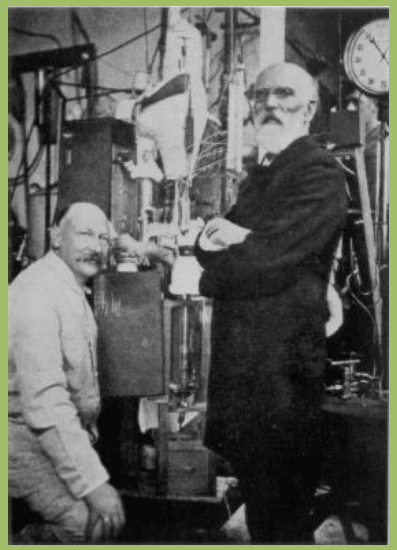
$$L \rightleftarrows V : v = 1 , \; P = P_v(T)$$




**Pression de vapeur saturante de l'eau**

**Cannettes compactées !**

# En abaissant la température



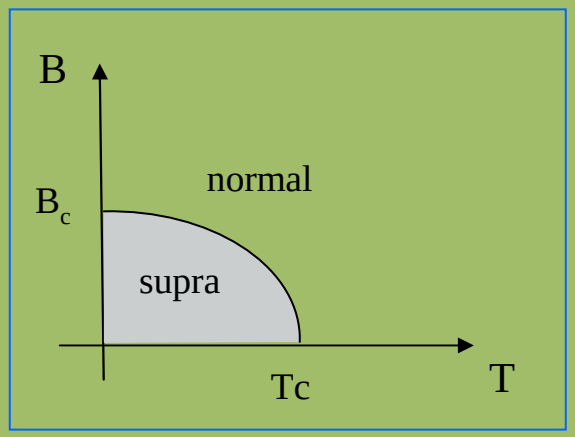
Kamerlingh Onnes (1853-1926)

et Van der Waals (1837-1923)

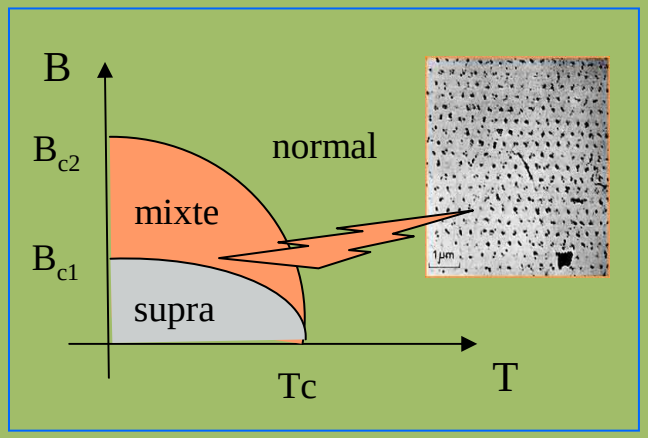
- **1911 : Découverte des supraconducteurs**
- **Les deux propriétés fondamentales :**
  - **L'absence de résistance**
  - **Le diamagnétisme**

# Types de supraconducteurs

**Les supraconducteurs de type I : diamagnétique parfait (effet Meissner)**

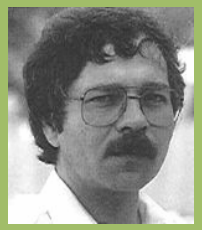



**Les supraconducteurs de type II : état mixte (vortex et ancrage)**

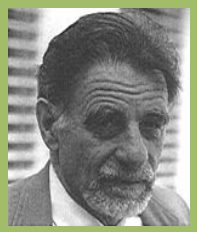


# Température extrême ?

- Les supraconducteurs « haute température »
- Les cuprates (1986)



Bednorz



Muller

Prix Nobel 1987

- Une barrière à franchir !

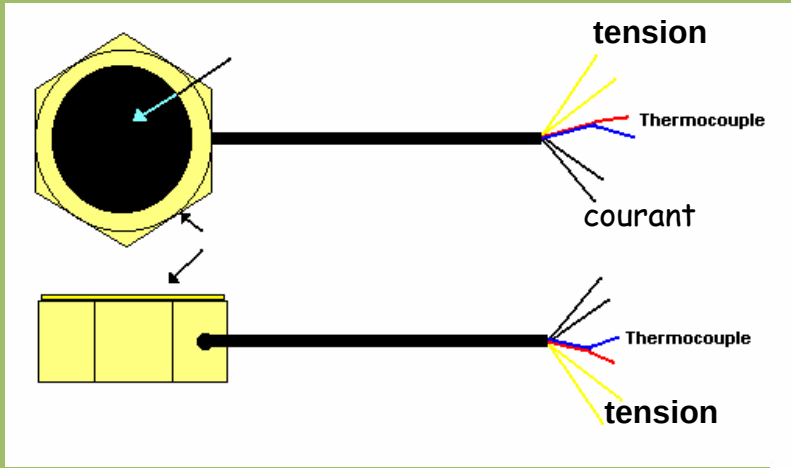
$T_{eb}(N_2)$ = 77 K

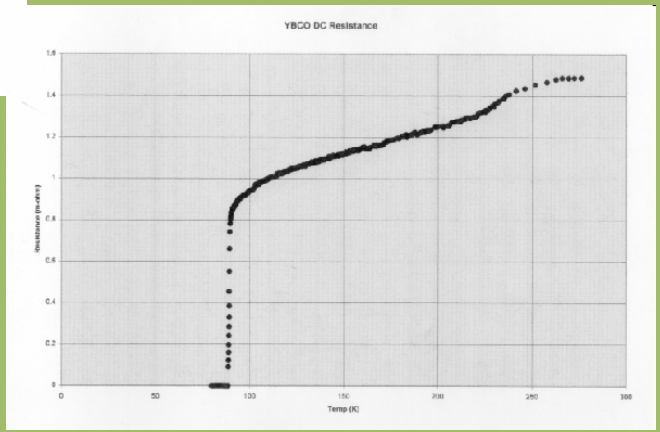
$YBa_2Cu_3O_7$ : 92 K

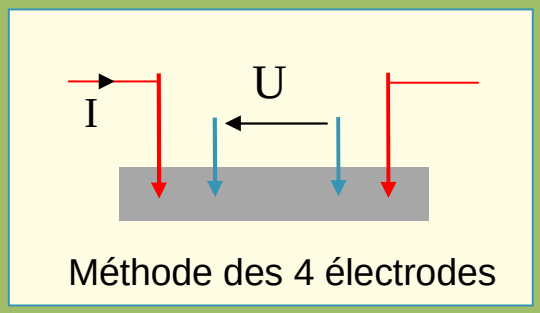
$Bi_2Sr_2Ca_2Cu_3O_{10}$ : 110 K

- Des supraconducteurs « voisins » du type II

# Annulation de la résistance




Méthode des 4 électrodes

# Lévitation

## Classique !

Lévitation d'un petit aimant au dessus d'un supraconducteur

## Un peu moins classique

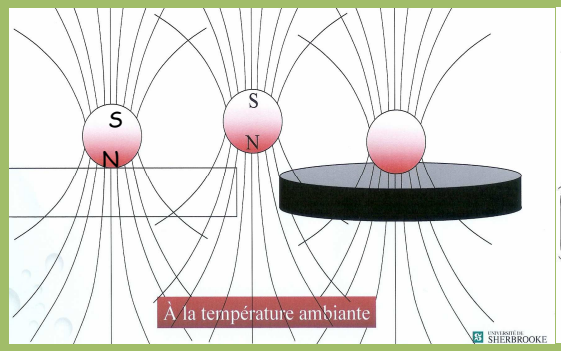
Lévitation d'un disque supraconducteur dans un champ non uniforme

## Vraiment surprenant !

Suspension d' un supraconducteur avec un aimant

# Un petit peu de théorie

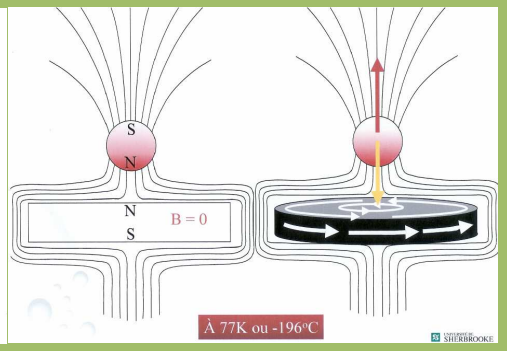
**Etat normal**




Le champ pénètre le matériau

**Supraconducteur (I)**

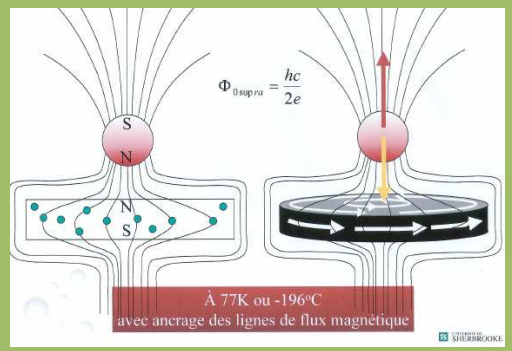
**diamagnétisme parfait**




**« Expulsion » du champ**

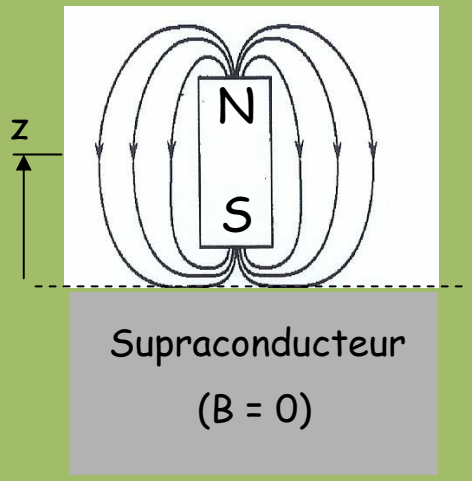
**Effet Meissner**

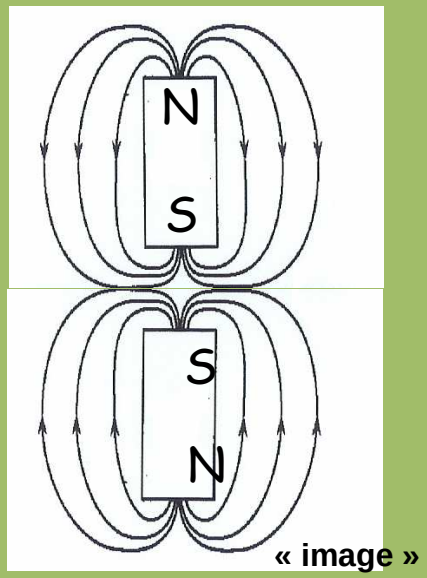
**Supraconducteur (II)**

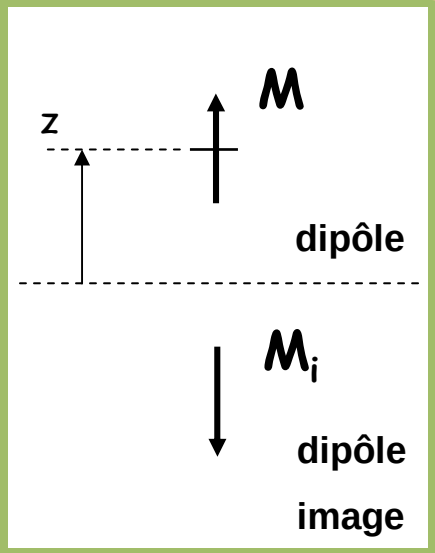



**L'expulsion non totale et ancrage**

# Un modélisation très simple



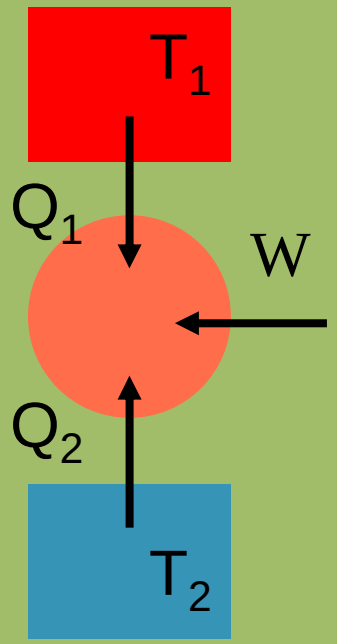

$$U_m = \frac{\mu_o M^2}{32\pi z^3} \quad ; \quad F = -\frac{\partial U_m}{\partial z} = \frac{3\mu_o M^2}{32\pi z^4} \Rightarrow z_e = \left(\frac{3\mu_o M^2}{32\pi mg}\right)^{1/4}$$

# Les principes de la thermodynamique

## Machines dithermes cycliques

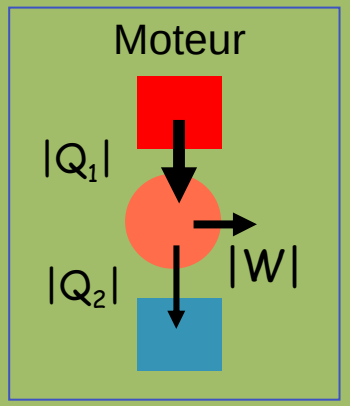
**Sadi Carnot**

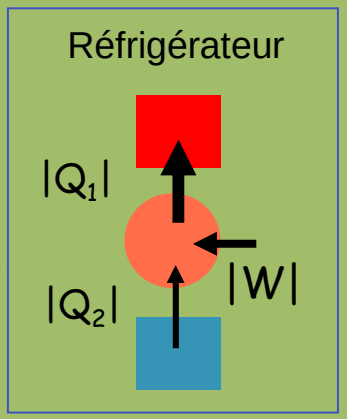
**(1796-1832)**




$$Q_1 + Q_2 + W = 0$$

$$\frac{Q_1}{T_1} + \frac{Q_2}{T_2} \leq 0$$

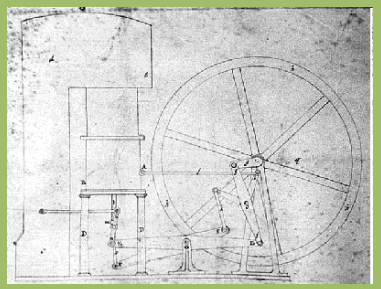


# Le moteur de Stirling

**R.Stirling**

**1790-1878**

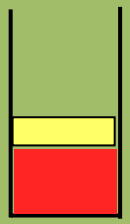


**Brevet 1816**

**Moteurs « jouets »**

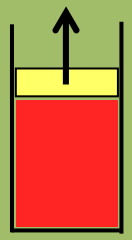
# Principe de base

12



Chauffage isochore

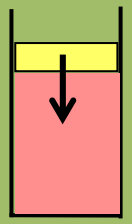
$T_2 \rightarrow T_1$



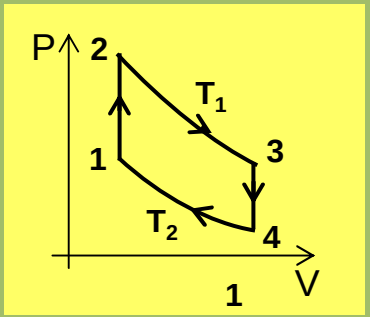
23

Détente isotherme

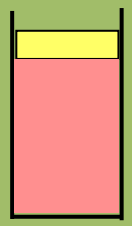
41



Compression isotherme




**Cycle de Stirling**



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Refroidissement isochore

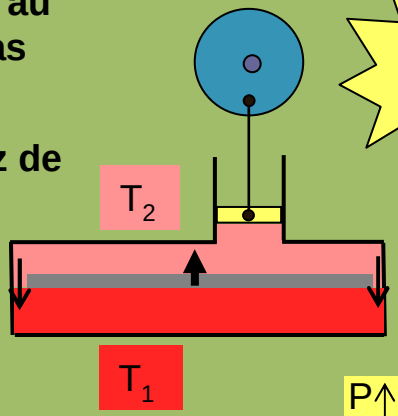
$T_1 \rightarrow T_2$

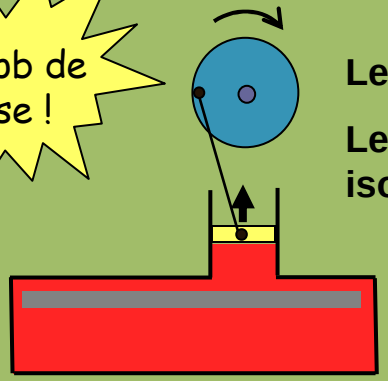
# Machine à déplaceur

**Le piston est au point mort bas**

**Le déplaceur chasse le gaz de H vers B**

$V \approx cte$



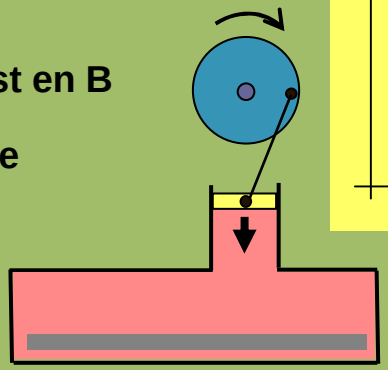


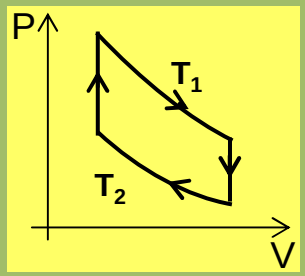
**Le déplaceur est en H**

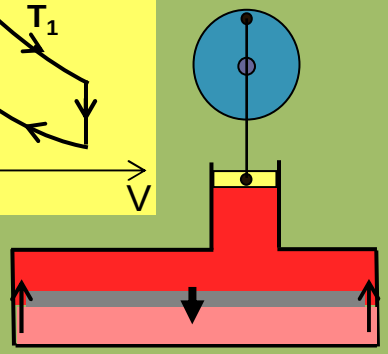
**Le gaz subit une détente isotherme ($T_1$)**

**Le déplaceur est en B**

**Le gaz subit une compression isotherme ($T_2$)**





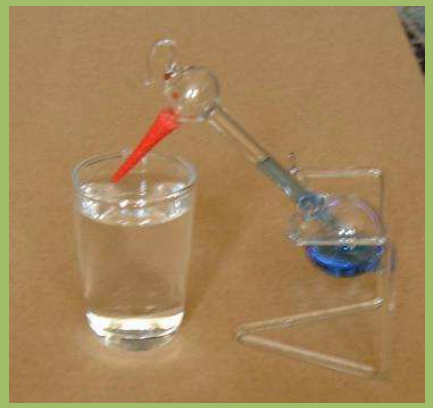



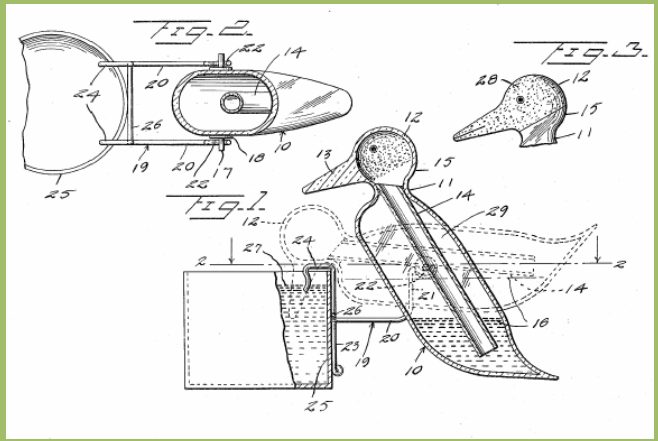
**Le piston est au point mort haut**

**Le déplaceur chasse le gaz de B vers H**

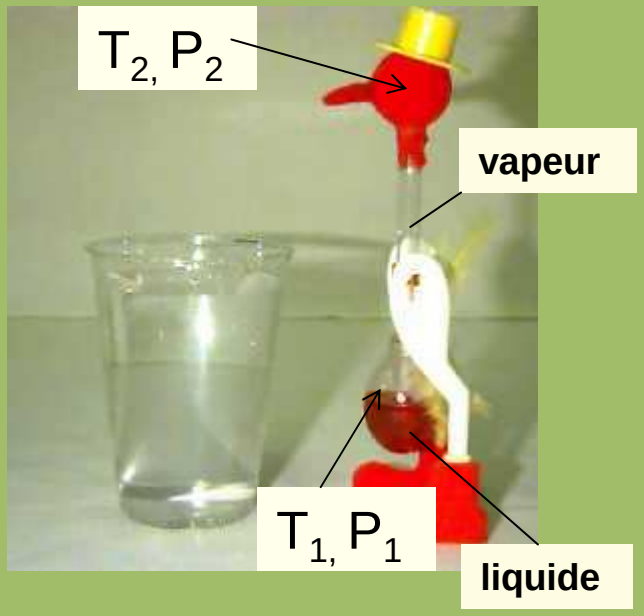
$V \approx cte$

# L'oiseau buveur





# Un moteur thermique !




## Les deux sources

- La source *froide* : évaporation de l'eau au niveau de la tête
- La source *chaude* : l'atmosphère ambiante
- Un fluide volatil ($CH_2Cl_2$)

Equilibre : liquide - vapeur

Différence de température

$\Rightarrow$ différence de pression

# Principe de fonctionnement

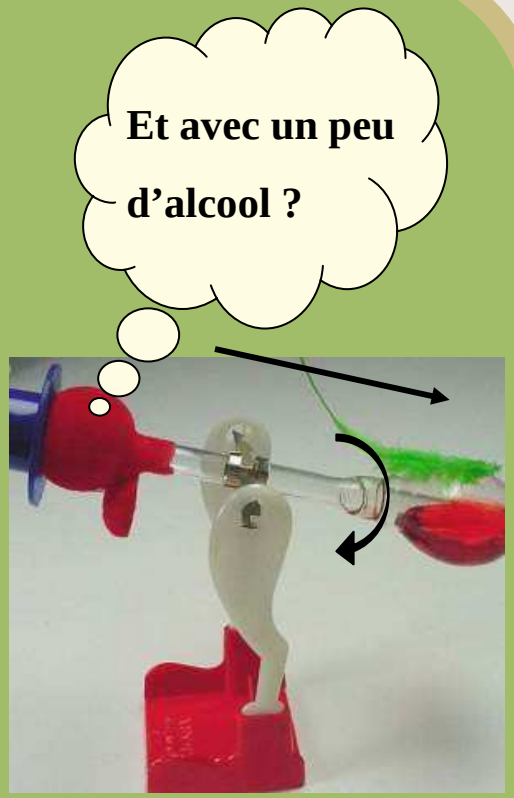
Ascension du liquide et déplacement du centre de gravité

Basculement autour de l'axe de rotation

Plongée de la tête dans l'eau

Emergence du tube et reflux du liquide

Redressement de l'oiseau …



# Thermoacoustique !

## Onde sonore : une évolution adiabatique !

**I.Newton**

**1643-1727**

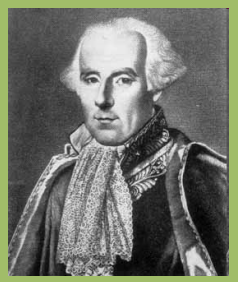
$$c = \sqrt{\frac{RT}{M}}$$

**détente** **compression**

Évolution d'une particule de fluide

$\Delta P \approx 0{,}1\,\mathrm{Pa}$, $\Delta \mathrm{T} \approx 10^{-4}\,\mathrm{K}$

$$c = \sqrt{\frac{\gamma RT}{M}}$$

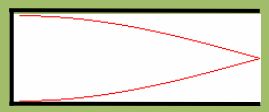


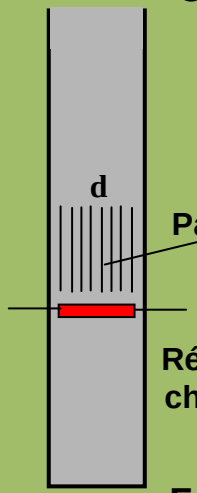
**P.S.Laplace**

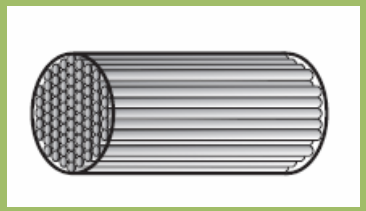
**1749-1827**

# Moteur thermoacoustique

## Tube de Sondhauss





$$d \approx 4\delta = \sqrt{\frac{K}{\rho c_P f}}$$

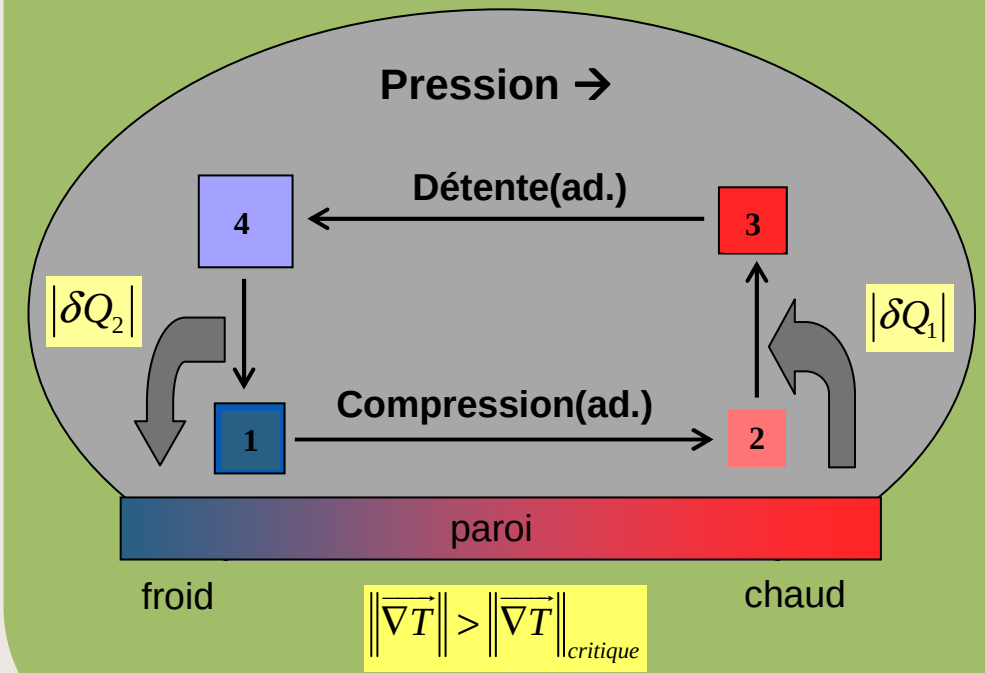
ni adiabatique

ni isotherme

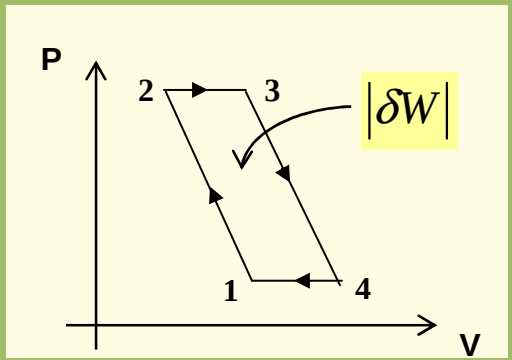
## Tube de Taconis

# Principe

## Évolution simplifiée d'une particule fluide



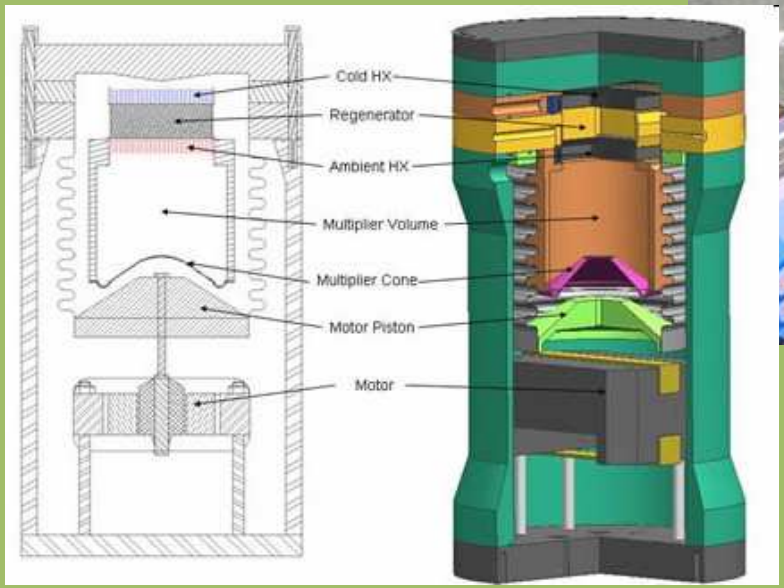

$$\left\|\overrightarrow{\nabla T}\right\| > \left\|\overrightarrow{\nabla T}\right\|_{critique}$$




Cas moteur

# Réfrigérateur thermoacoustique

**Des glaces thermoacoustiques !**



**S.Garrett**