



INTRODUÇÃO

TECNOLOGIA DE VÁCUO : MET



Vácuo é uma palavra de origem grega que significa **vazio**

Vácuo é qualquer ambiente com pressão **inferior à atmosférica**

Unidades de Pressão

1 atm = 760 mm Hg = 760 Torr = 1,01325 bar = 101.325 Pa

1 atm = 10,33 m H₂O

Bar é um múltiplo da Bária: 1 bar = 10⁶ bárias

Bária: unidade de pressão no C.G.S (1 bária = dyn/cm²)

TECNOLOGIA DE VÁCUO : MET



Por que não há vácuo absoluto?

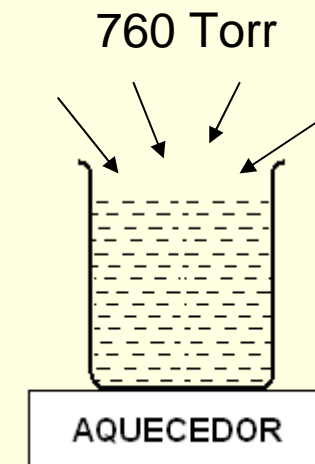
PRESSÃO DE VAPOR

Pressão de Vapor (p^*) é a pressão exercida por um vapor quando este está em equilíbrio com o líquido ou sólido que lhe deu origem a uma dada temperatura.

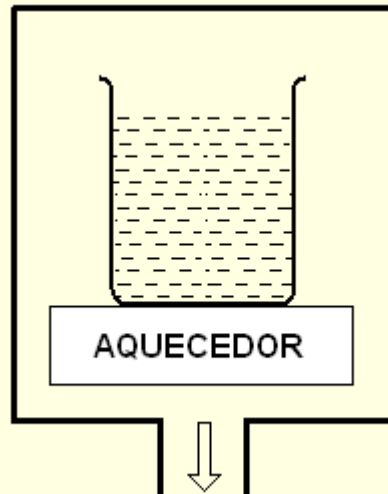
Água a 20 °C $\Rightarrow p^* = 17,5 \text{ mm Hg} = 17,5 \text{ Torr}$

Água a 60 °C $\Rightarrow p^* = 150,4 \text{ mm Hg} = 150,4 \text{ Torr}$

Água a 100 °C $\Rightarrow p^* = 1 \text{ atm} = 760 \text{ Torr}$



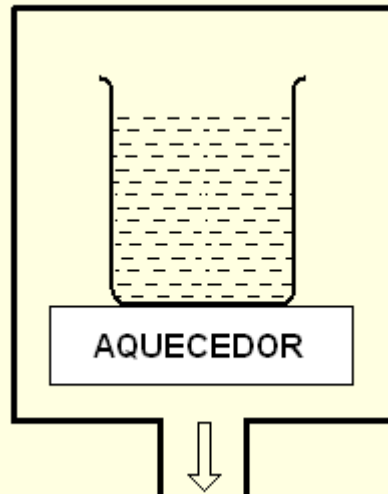
TECNOLOGIA DE VÁCUO : MET



Água a 20 °C

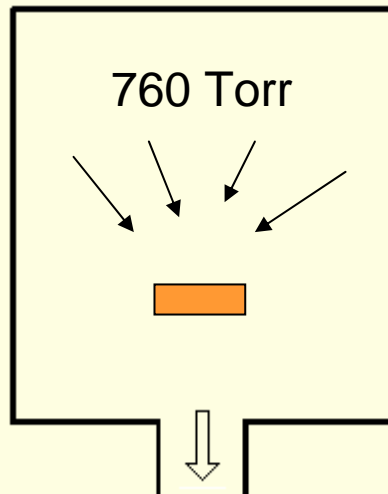
$p^* = 17,5 \text{ mm Hg} = 17,5 \text{ Torr}$

TECNOLOGIA DE VÁCUO : MET



Água a 20 °C

$$p^* = 17,5 \text{ mm Hg} = 17,5 \text{ Torr}$$



Zinco a 20 °C

$$p^* = 9,76 \times 10^{-13} \text{ mm Hg} = 9,76 \times 10^{-13} \text{ Torr}$$

Alumínio a 20 °C

$$p^* = 5,37 \times 10^{-29} \text{ mm Hg} = 5,37 \times 10^{-29} \text{ Torr}$$

TECNOLOGIA DE VÁCUO : MET



Por que não há vácuo absoluto?

Temperatura (°C) para Pressões de Vapor (Torr)

Elemento	10 ⁻⁸	10 ⁻⁷	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³	10 ⁻²	10 ⁻¹	10 ⁰
Ag	574	626	685	752	832	922	1027	1162	1322
Al	685	742	812	887	972	1082	1217	1367	1557
Au	807	877	947	1032	1132	1252	1397	1567	1767
Cu	722	787	852	937	1027	1132	1257	1417	1617
Mo	1592	1702	1822	1957	2117	2307	2527	2787	3117
Ta	1957	2097	2237	2407	2587	2807	3057	3357	3707
Ti	1062	1137	1227	1327	1442	1577	1737	1937	2177
W	2117	2247	2407	2567	2757	2977	3227	3537	3917
Zn	123	147	177	209	247	292	344	408	487

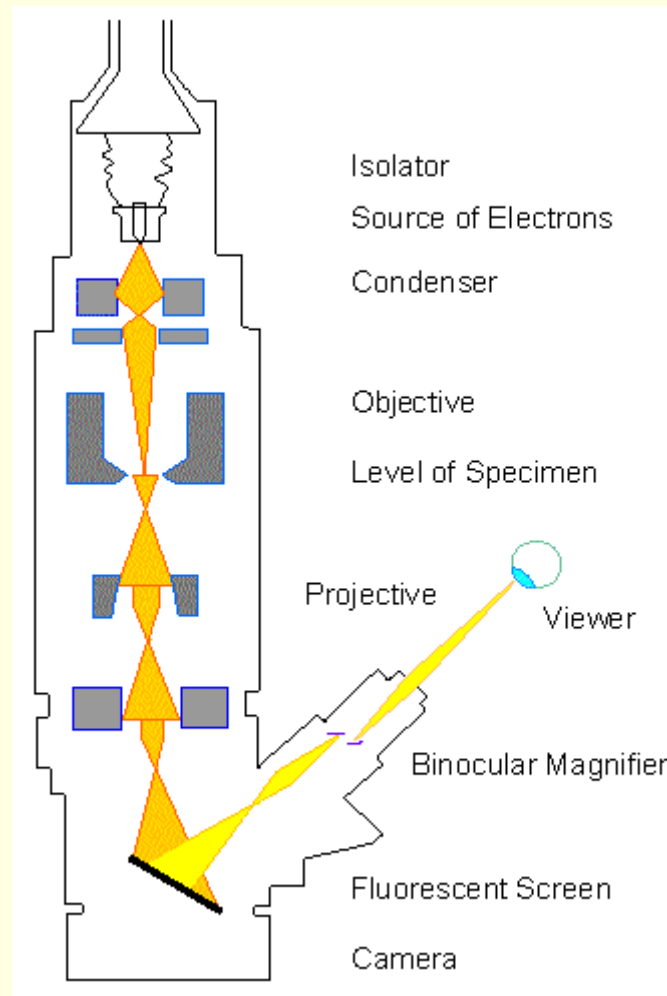
TECNOLOGIA DE VÁCUO : MET



Faixas de Vácuo

Descrição	Faixa
Baixo vácuo	760 a 25 Torr
Médio vácuo	25 a 10^{-3} Torr
Alto vácuo	10^{-3} Torr a 10^{-6} Torr
Altíssimo vácuo	10^{-6} Torr a 10^{-9} Torr
Ultra alto vácuo	10^{-9} Torr a 10^{-12} Torr
Extremo ultra alto vácuo	$p < 10^{-12}$ Torr

TECNOLOGIA DE VÁCUO : MET



TECNOLOGIA DE VÁCUO : MET



Por que as colunas em um MET estão em vácuo?

$$\lambda \text{ (cm)} = \frac{5 \times 10^{-3}}{p \text{ (Torr)}}$$

$$\left\{ \begin{array}{l} p = 10^{-3} \text{ Torr} \Rightarrow \lambda = 5 \text{ cm} \\ p = 10^{-4} \text{ Torr} \Rightarrow \lambda = 50 \text{ cm} \\ p = 10^{-5} \text{ Torr} \Rightarrow \lambda = 500 \text{ cm} \\ p = 10^{-6} \text{ Torr} \Rightarrow \lambda = 5000 \text{ cm} \end{array} \right.$$

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O nível de vácuo é determinado pelo **tipo de filamento** utilizado:

- Tungstênio $\Rightarrow 10^{-3}$ Pa ($7,5 \times 10^{-6}$ Torr)
- Cristal de LaB_6 $\Rightarrow 10^{-5}$ Pa ($7,5 \times 10^{-8}$ Torr)
- FEG $\Rightarrow 10^{-7}$ e 10^{-8} Pa ($7,5 \times 10^{-10}$ a $7,5 \times 10^{-11}$ Torr)

Qualidade do vácuo !



TECNOLOGIA DE VÁCUO : MET



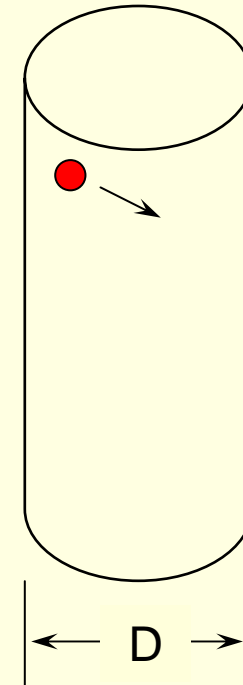
BOMBAS DE VÁCUO

REGIMES DE ESCOAMENTO

Escoamento Viscoso $\Rightarrow \lambda \ll D$

Escoamento Intermediário $\Rightarrow \lambda \cong D$

Escoamento Molecular $\Rightarrow \lambda \gg D$



FAIXA DE PRESSÃO DAS BOMBAS DE VÁCUO



BOMBAS DE JATO



BOMBAS MECÂNICAS



BOMBAS ROOTS



BOMBAS DE SORÇÃO



BOMBAS TURBOMOLECULARES



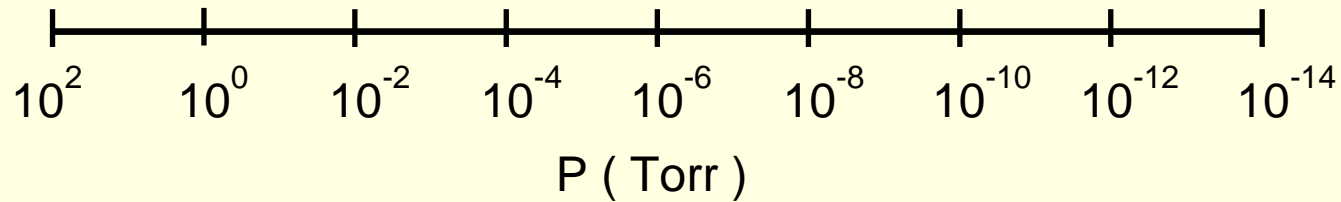
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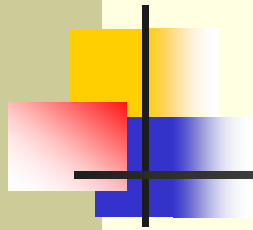


BOMBAS IÔNICAS



BOMBAS CRIOGÊNICAS

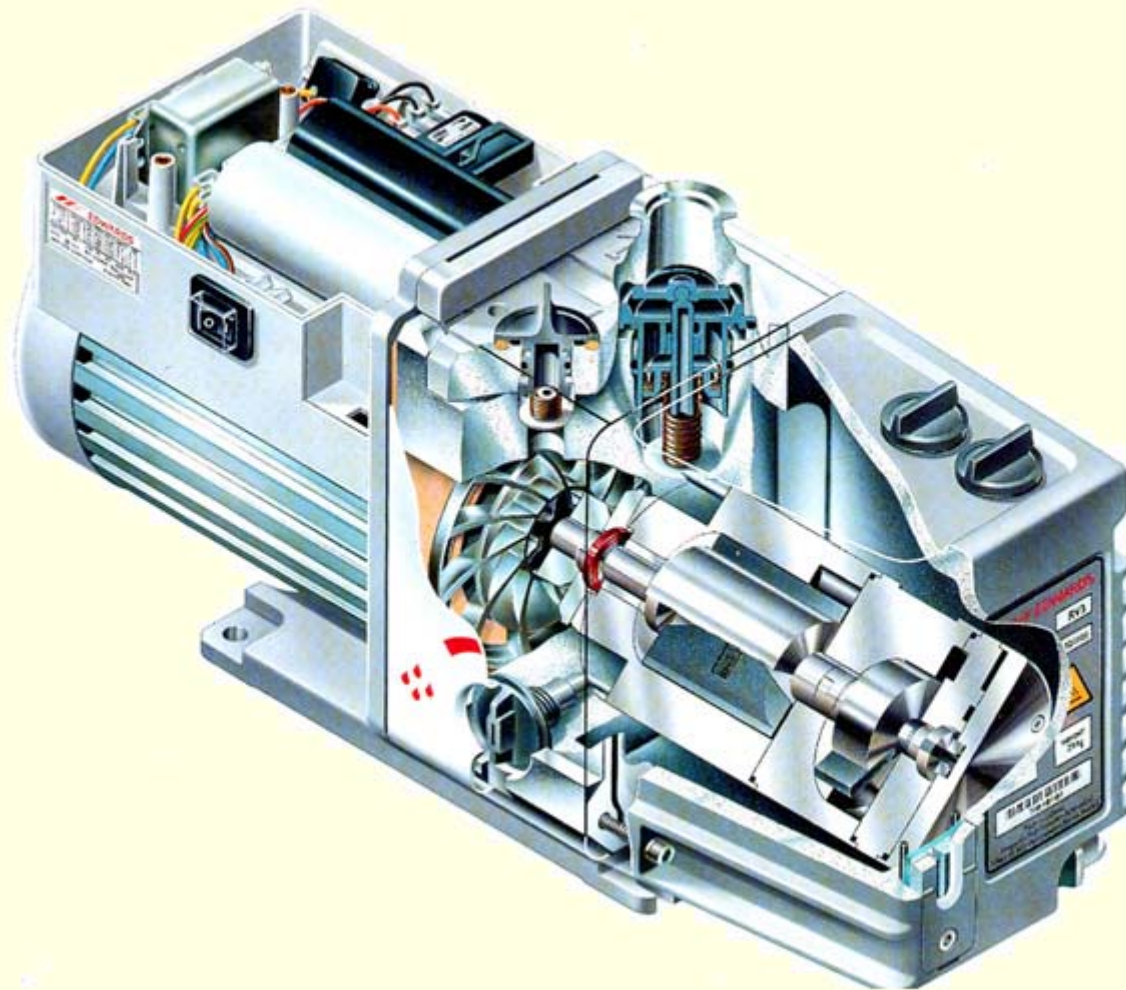




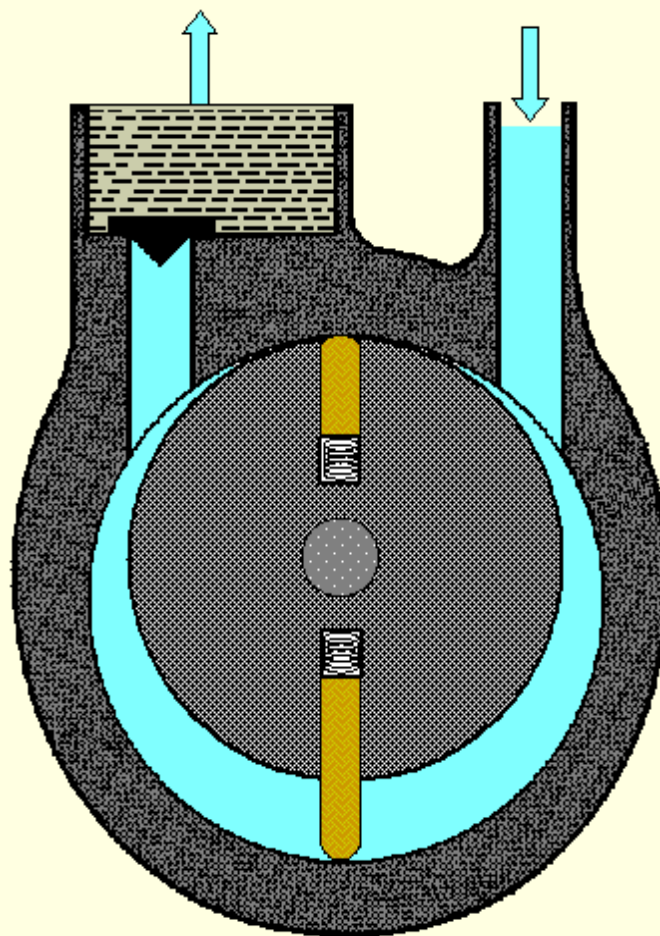
MECÂNICAS SELADAS A ÓLEO



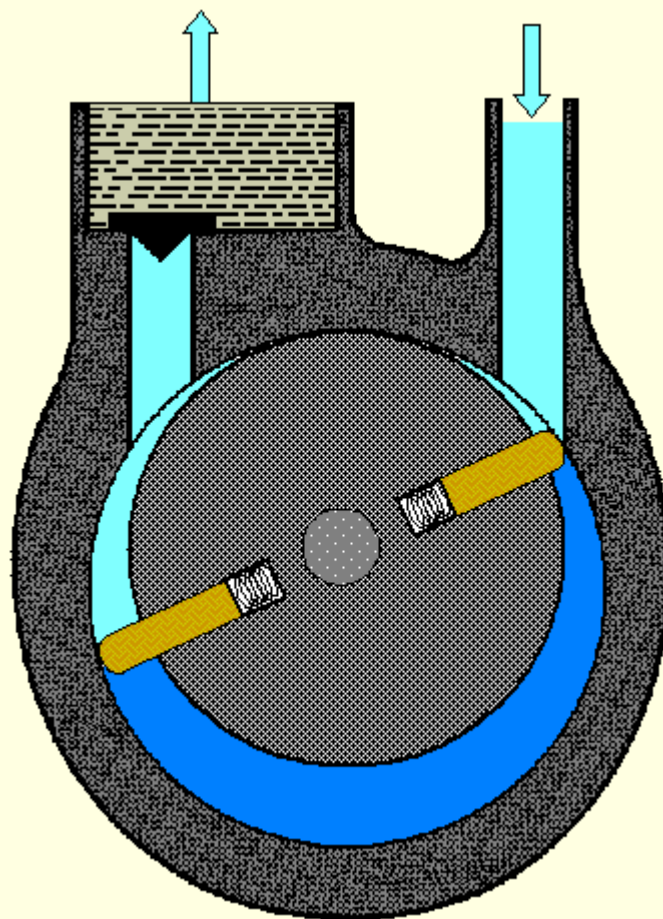
MECÂNICA SELADA A ÓLEO



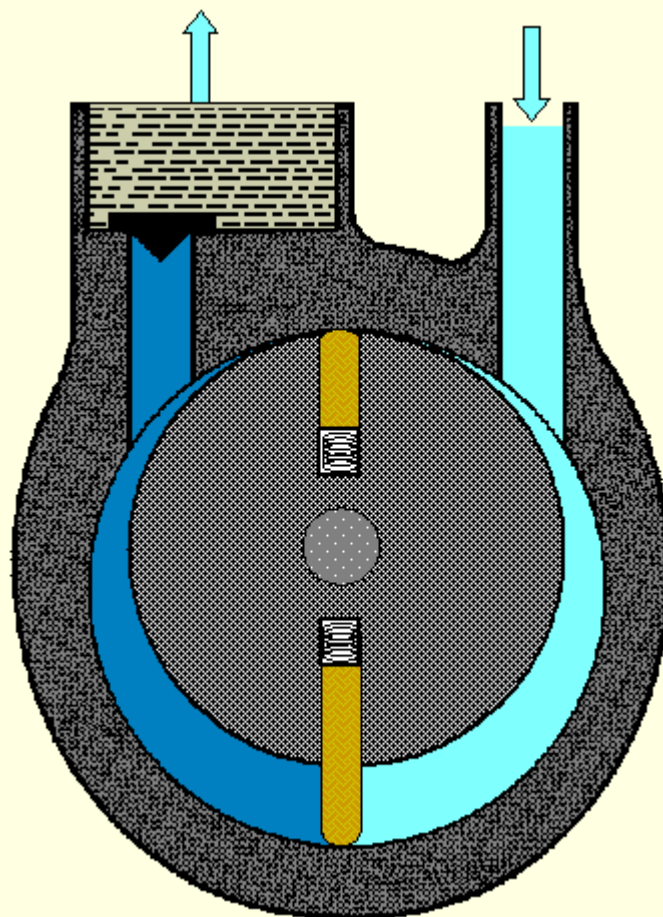
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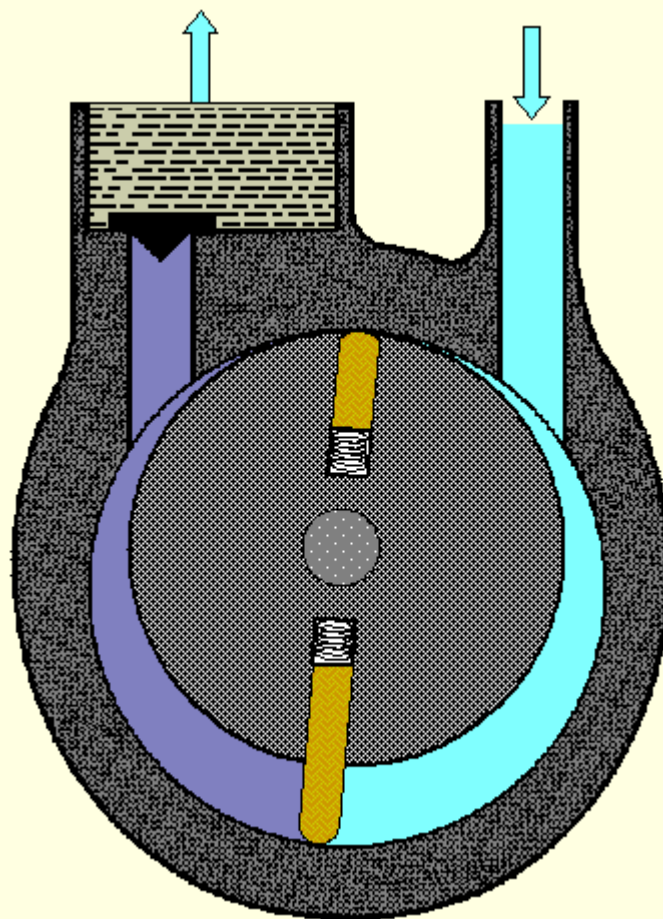
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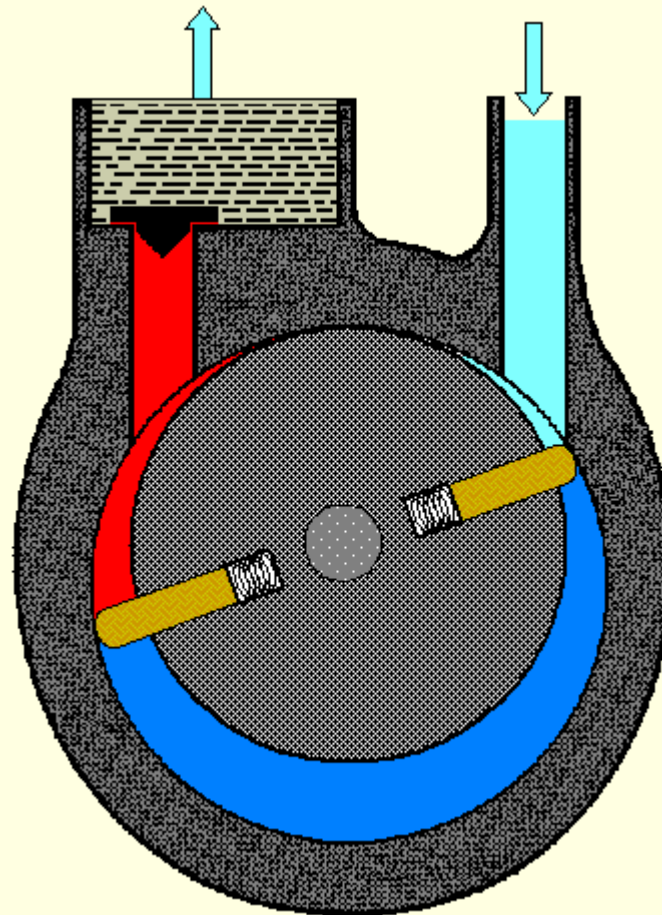
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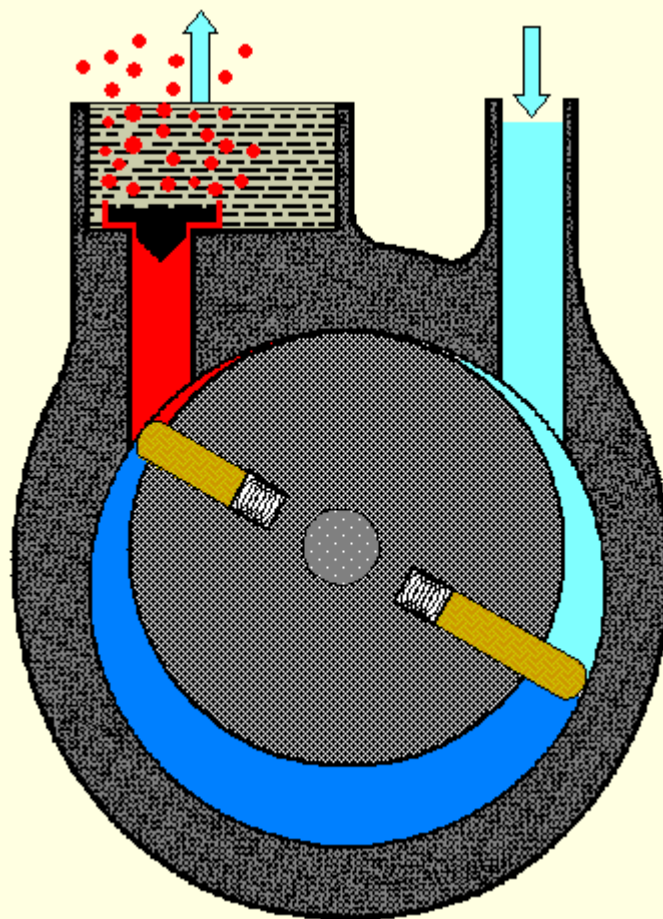
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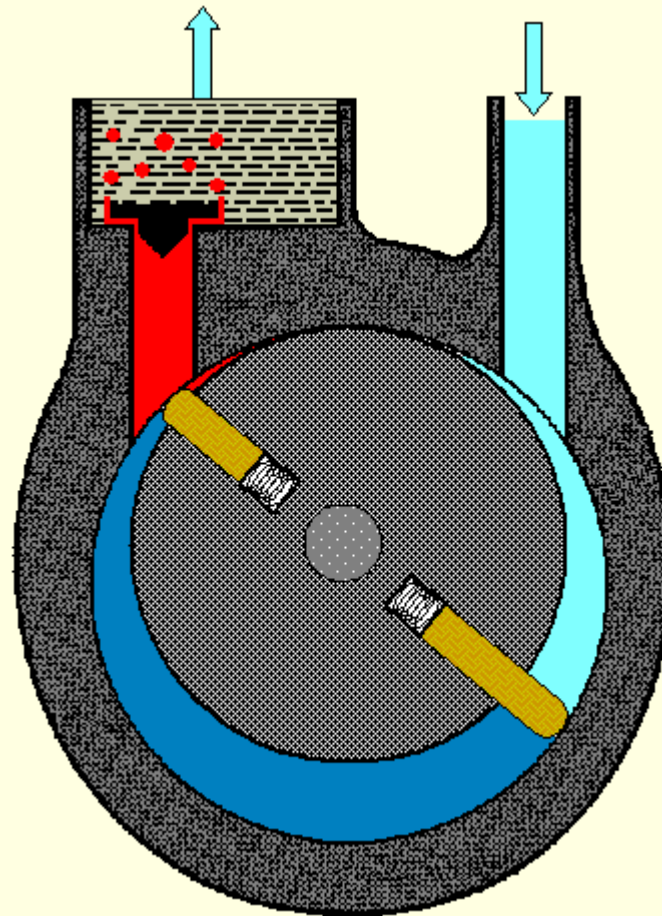
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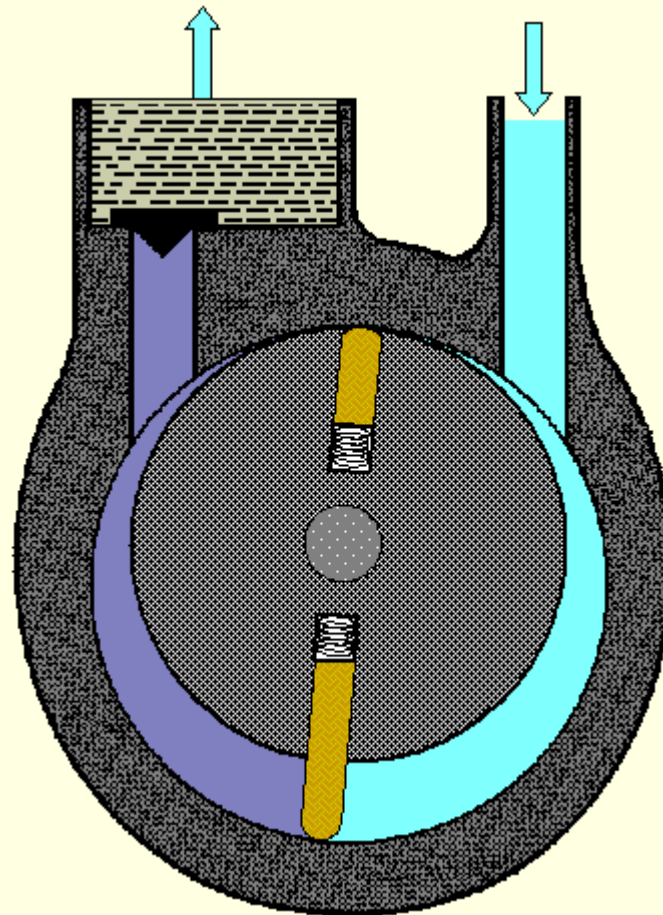
MECÂNICA SELADA A ÓLEO



MECÂNICA SELADA A ÓLEO



MECÂNICA SELADA A ÓLEO



$$p_{\text{H}_2\text{O}}^* (20 \text{ }^\circ\text{C}) = 23,3 \text{ mbar}$$

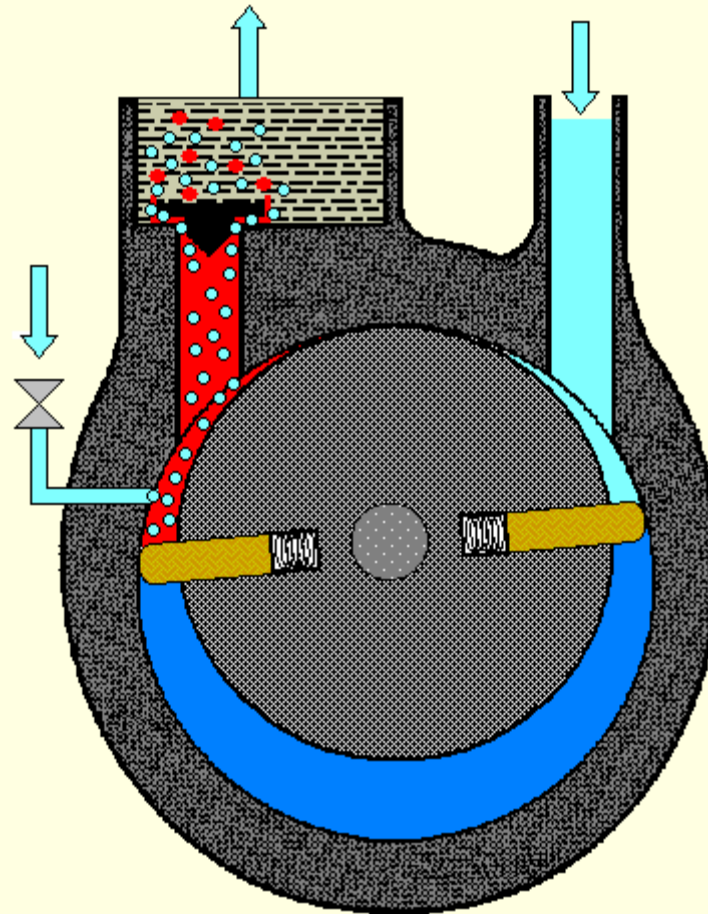
$$p_{\text{H}_2\text{O}}^* (60 \text{ }^\circ\text{C}) = 200,0 \text{ mbar}$$

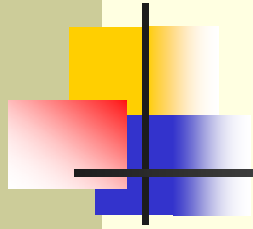
$$\frac{200,0 \text{ mbar}}{23,3 \text{ mbar}} = 8,6$$

MECÂNICA SELADA A ÓLEO



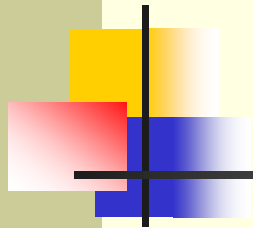
Gas ballast



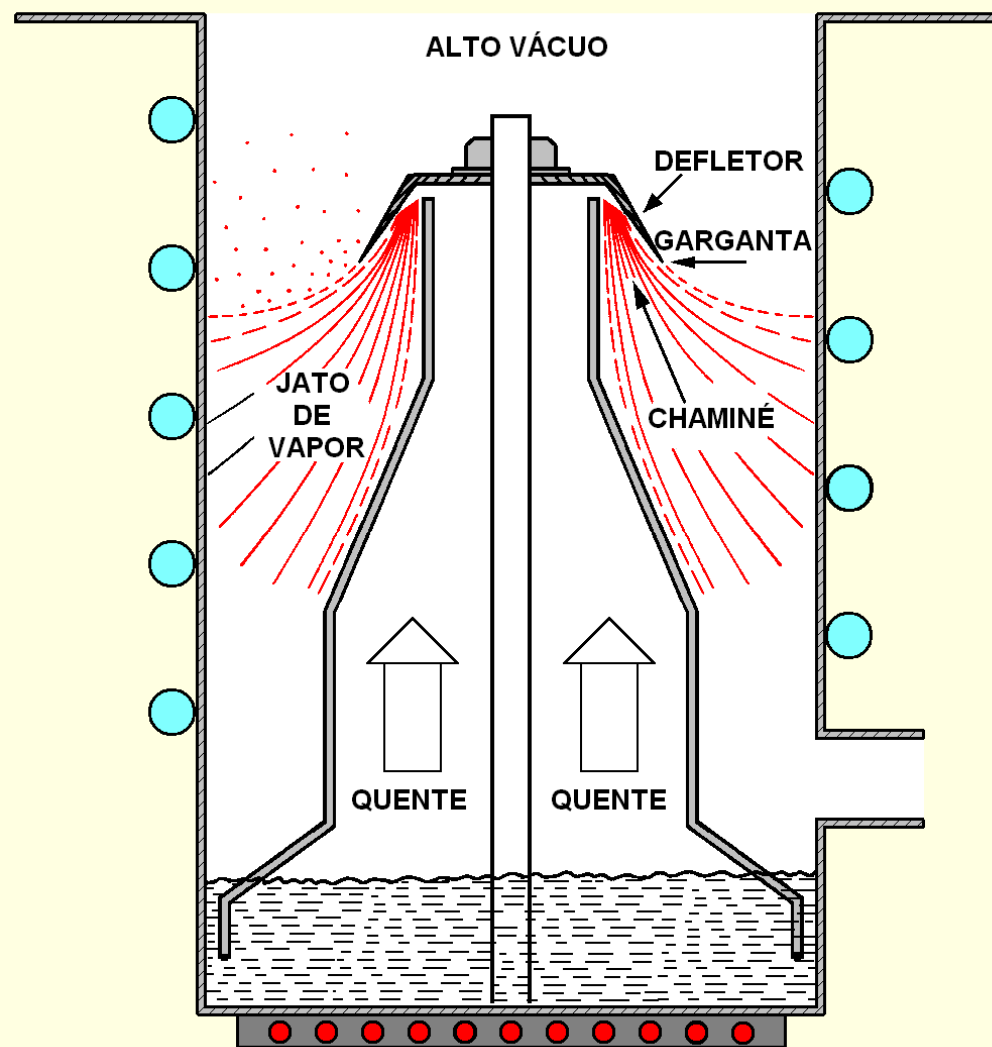


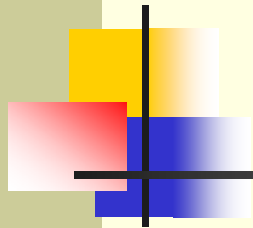
BOMBAS DE DIFUSÃO



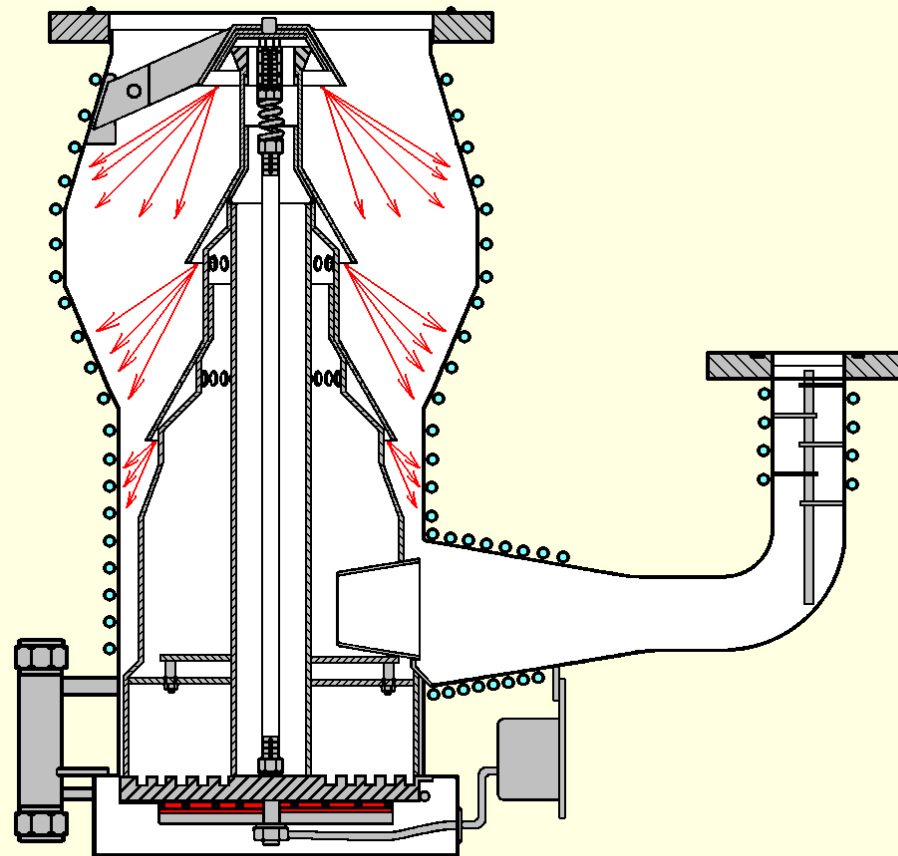
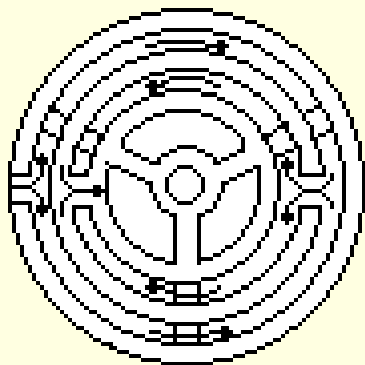


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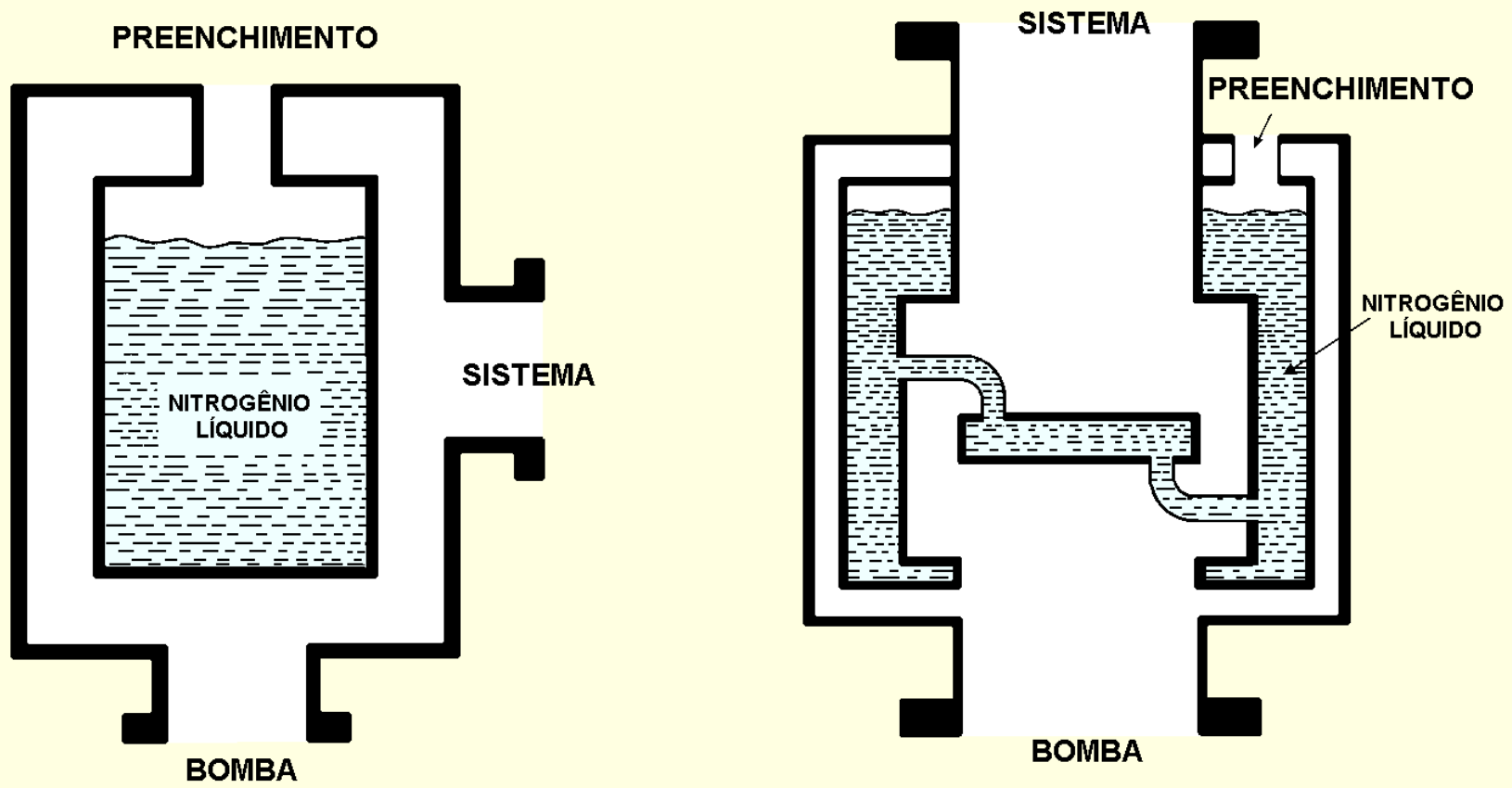




BOMBAS DE DIFUSÃO



BOMBAS DE DIFUSÃO





BOMBAS DE DIFUSÃO



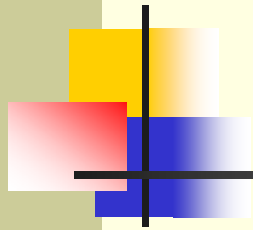
$p_{\text{final}} \sim 10^{-9}$ Torr

Óleos

Santovac $\Rightarrow p^* = 4 \times 10^{-10}$ Torr

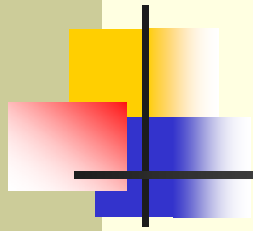
Fomblim $\Rightarrow p^* = 10^{-9}$ Torr

Silicone $\Rightarrow p^* = 10^{-9}$ Torr

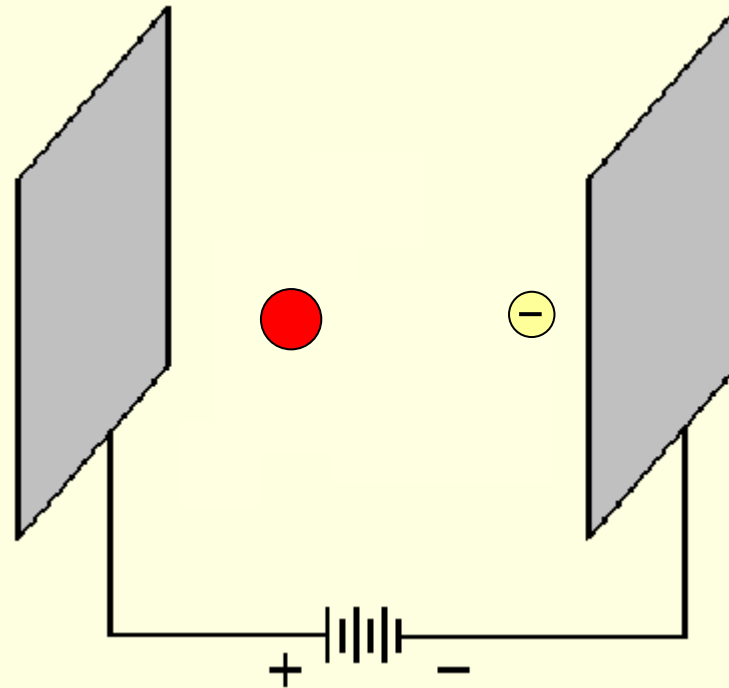


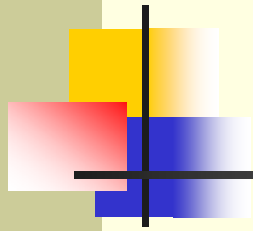
BOMBAS IÔNICAS



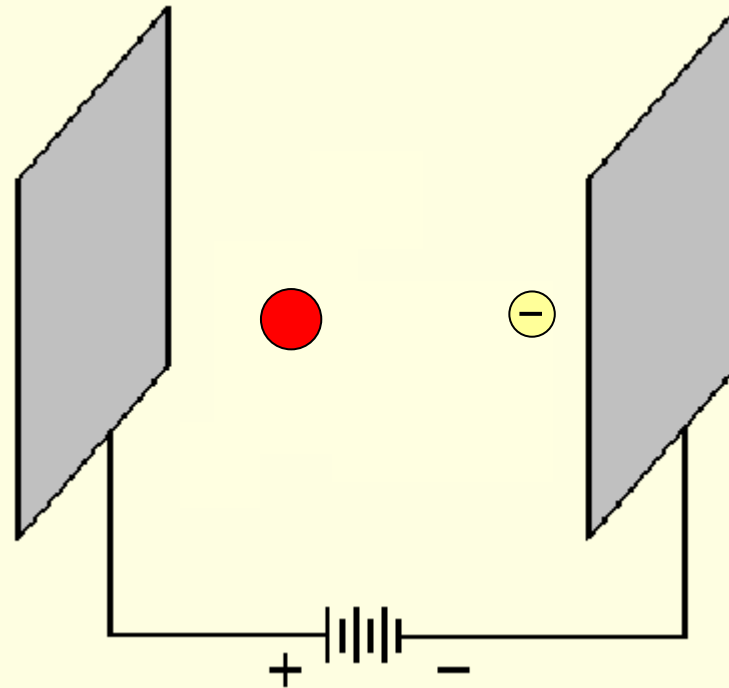


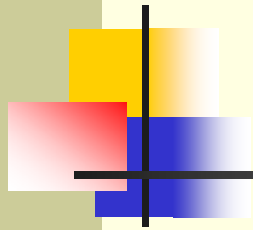
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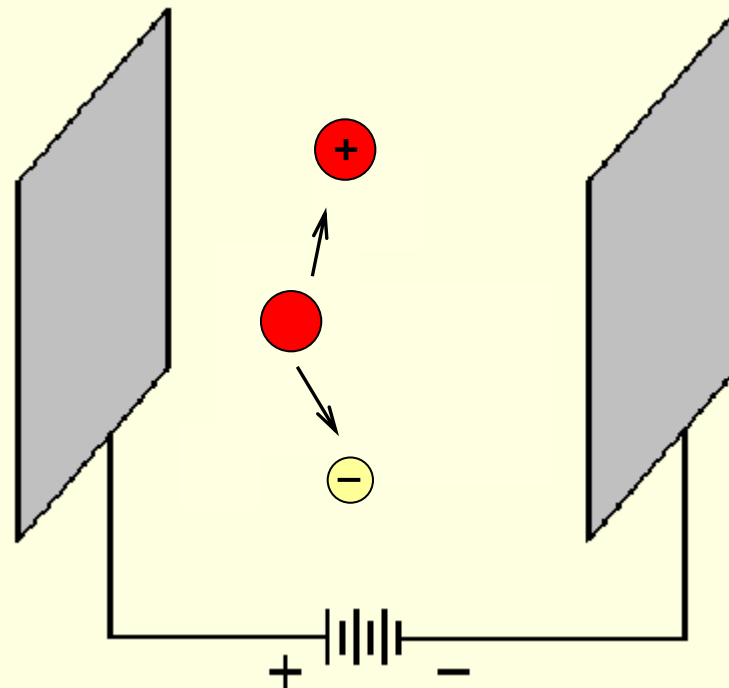


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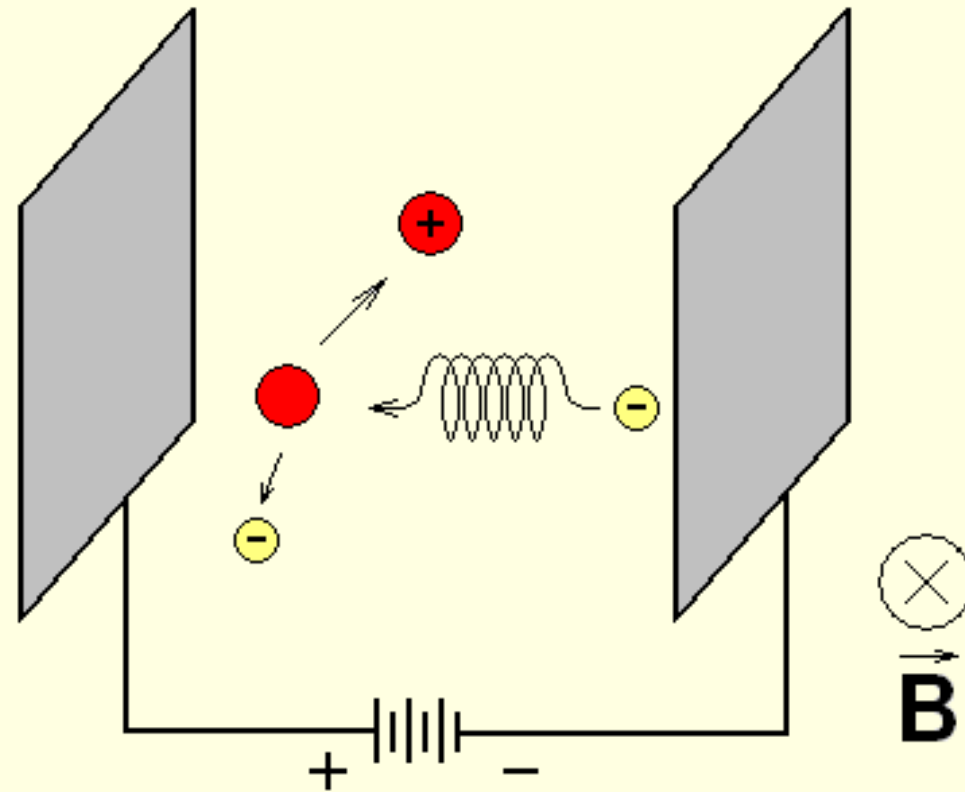


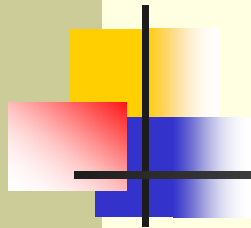


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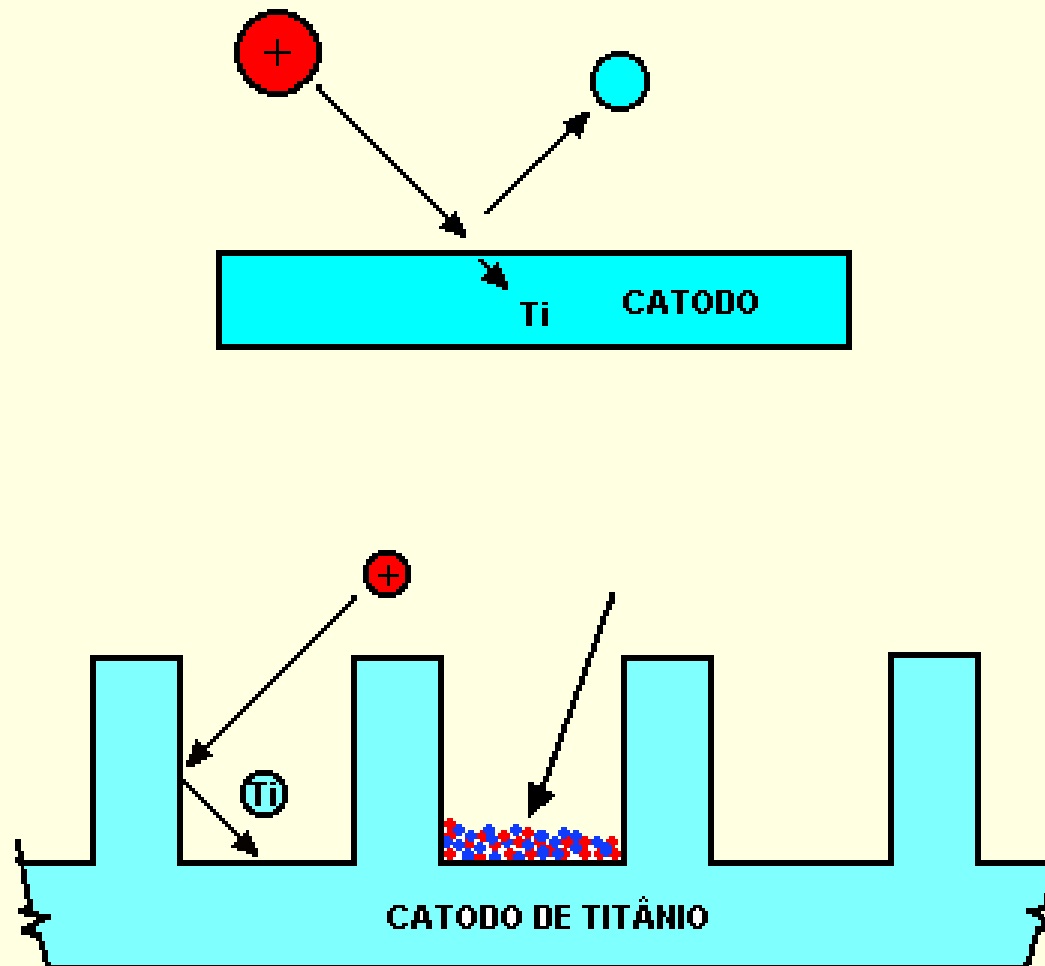


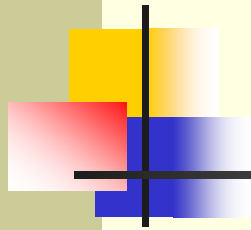
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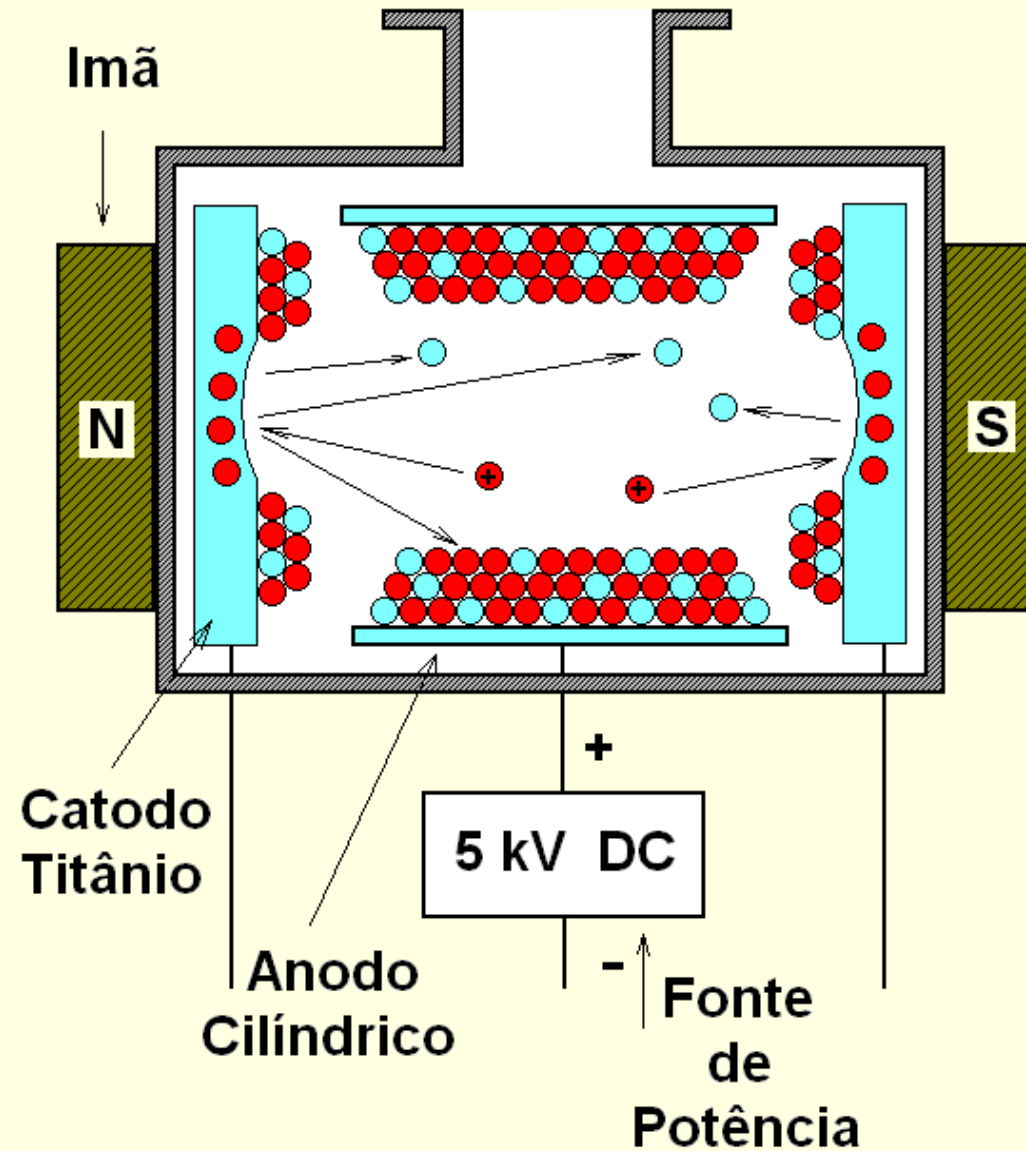


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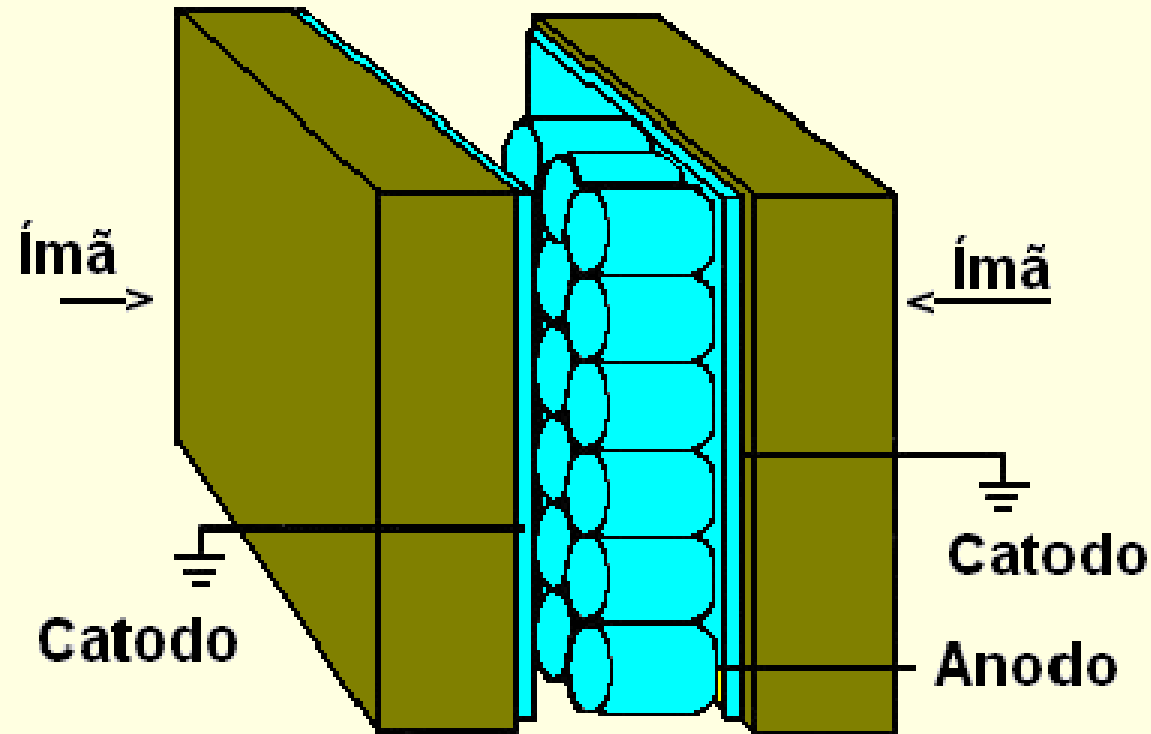




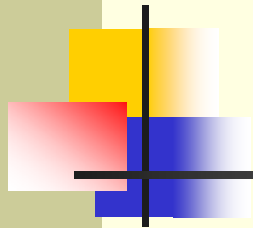
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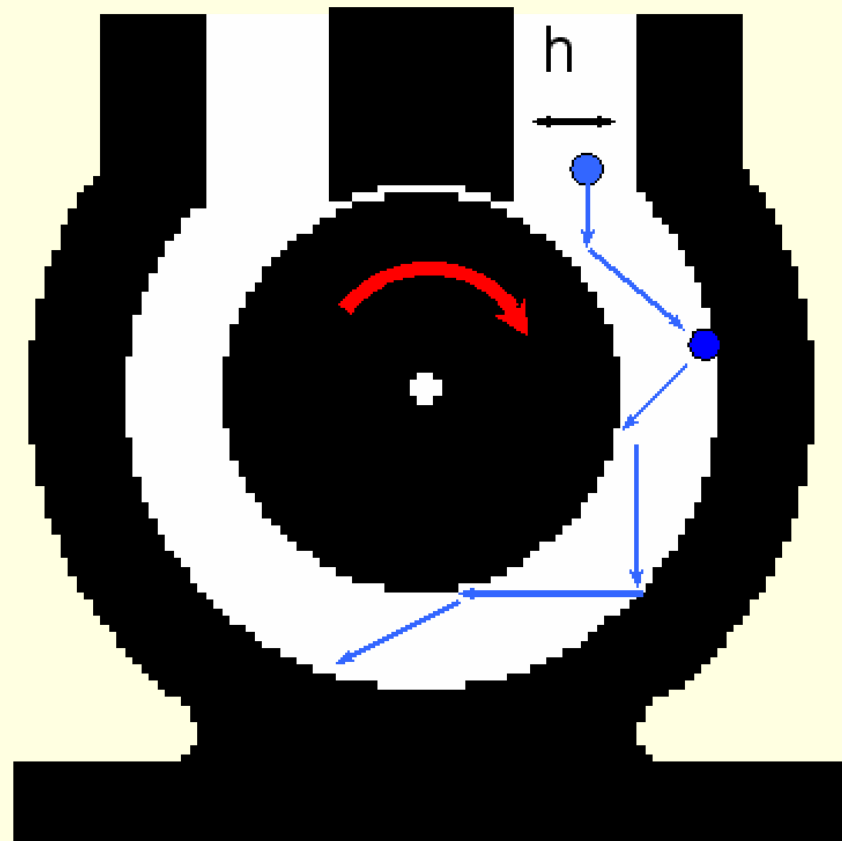
$p_{\text{final}} \sim 10^{-11}$ Torr



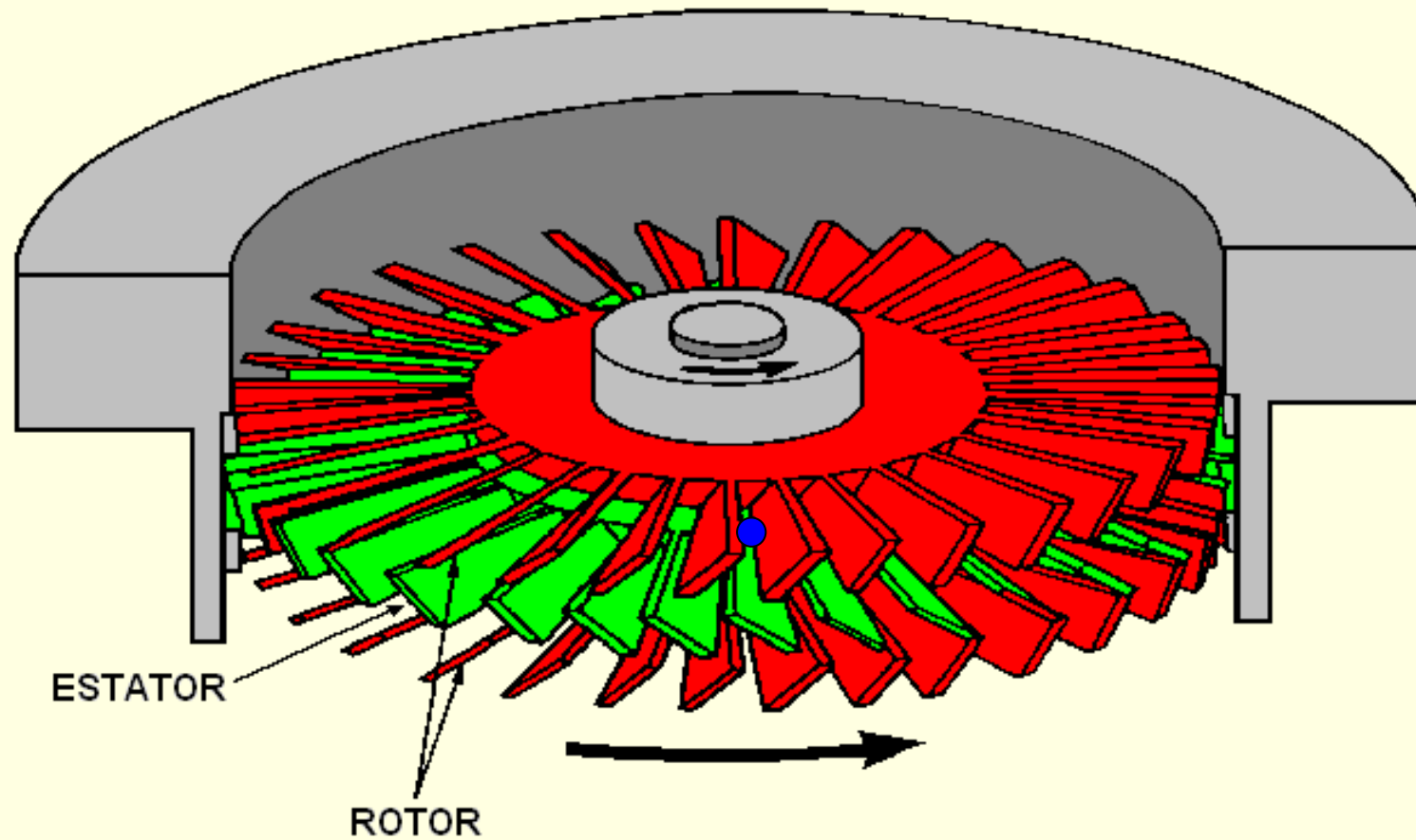
BOMBAS TURBOMOLECULARES



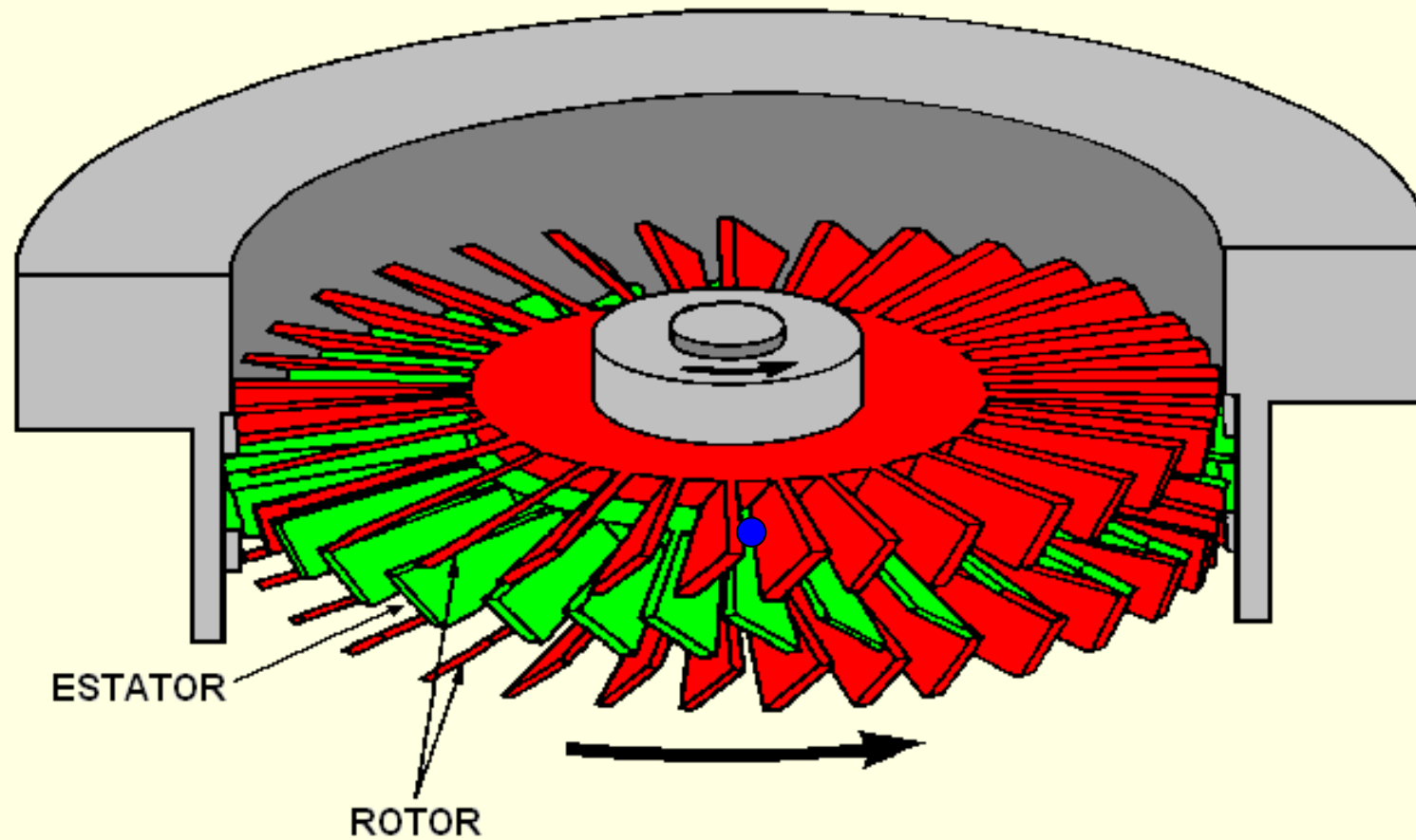
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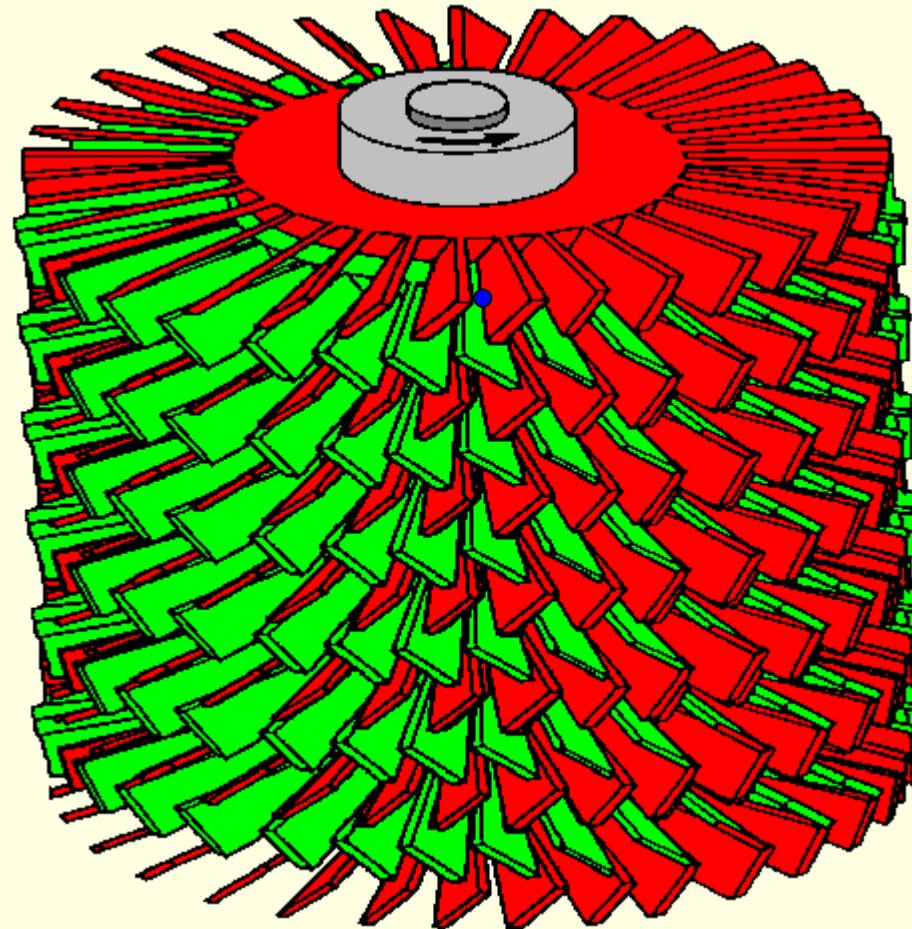
BOMBAS TURBOMOLECULARES



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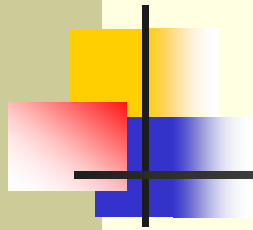


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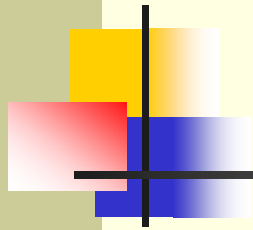


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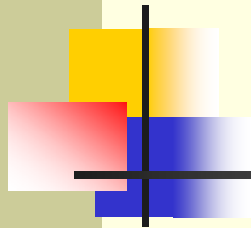


MEDIDORES DE PRESSÃO



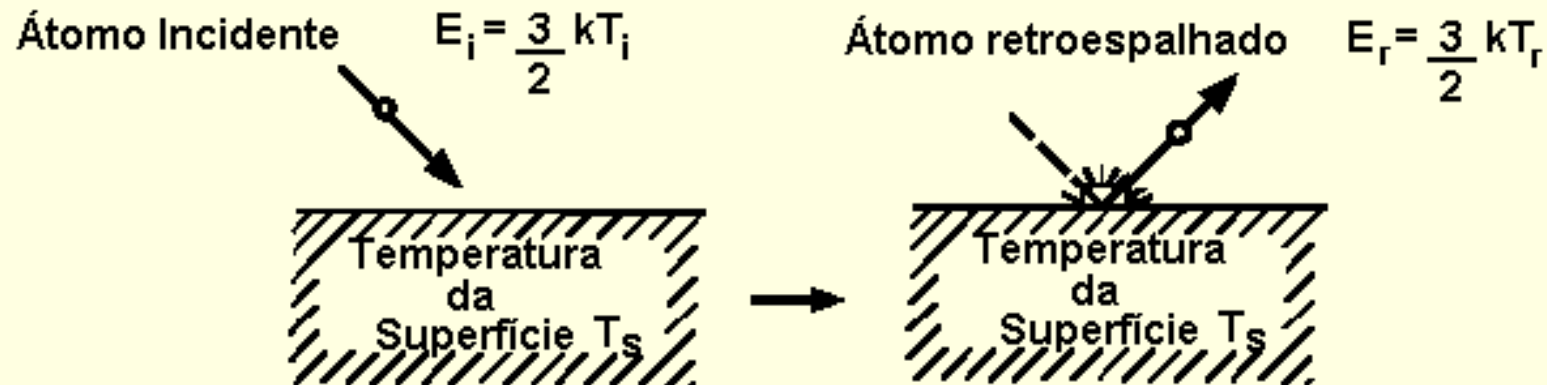
MEDIDOR PIRANI





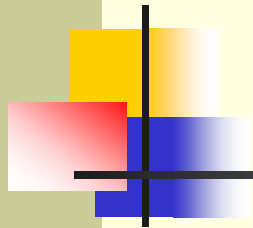
MEDIDOR PIRANI

TROCA DE CALOR GÁS - SUPERFÍCIE (COEFICIENTE DE ACOMODAÇÃO)

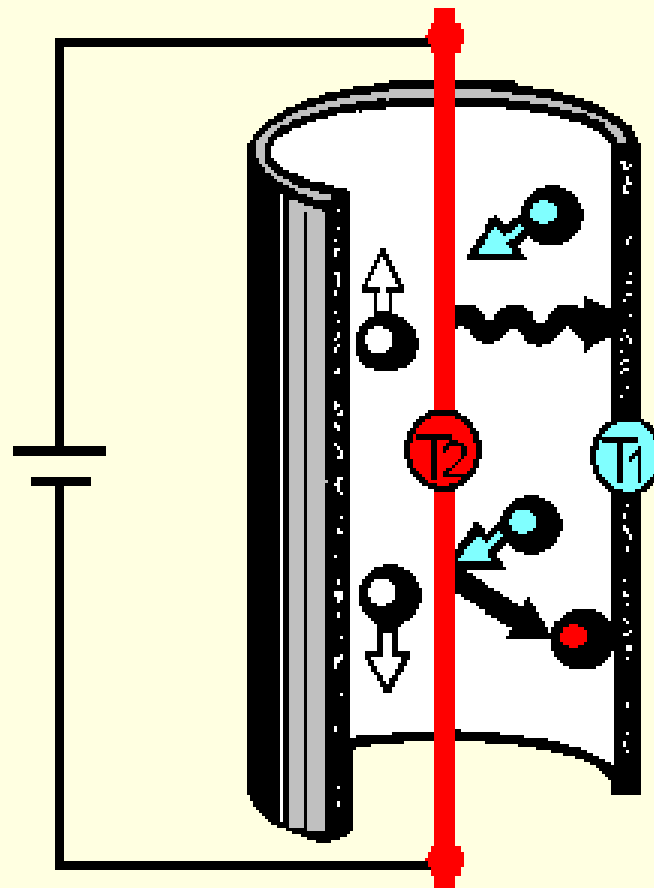


$$\text{Energia cinética do átomo} = \frac{3}{2} kT \text{ (média)}$$

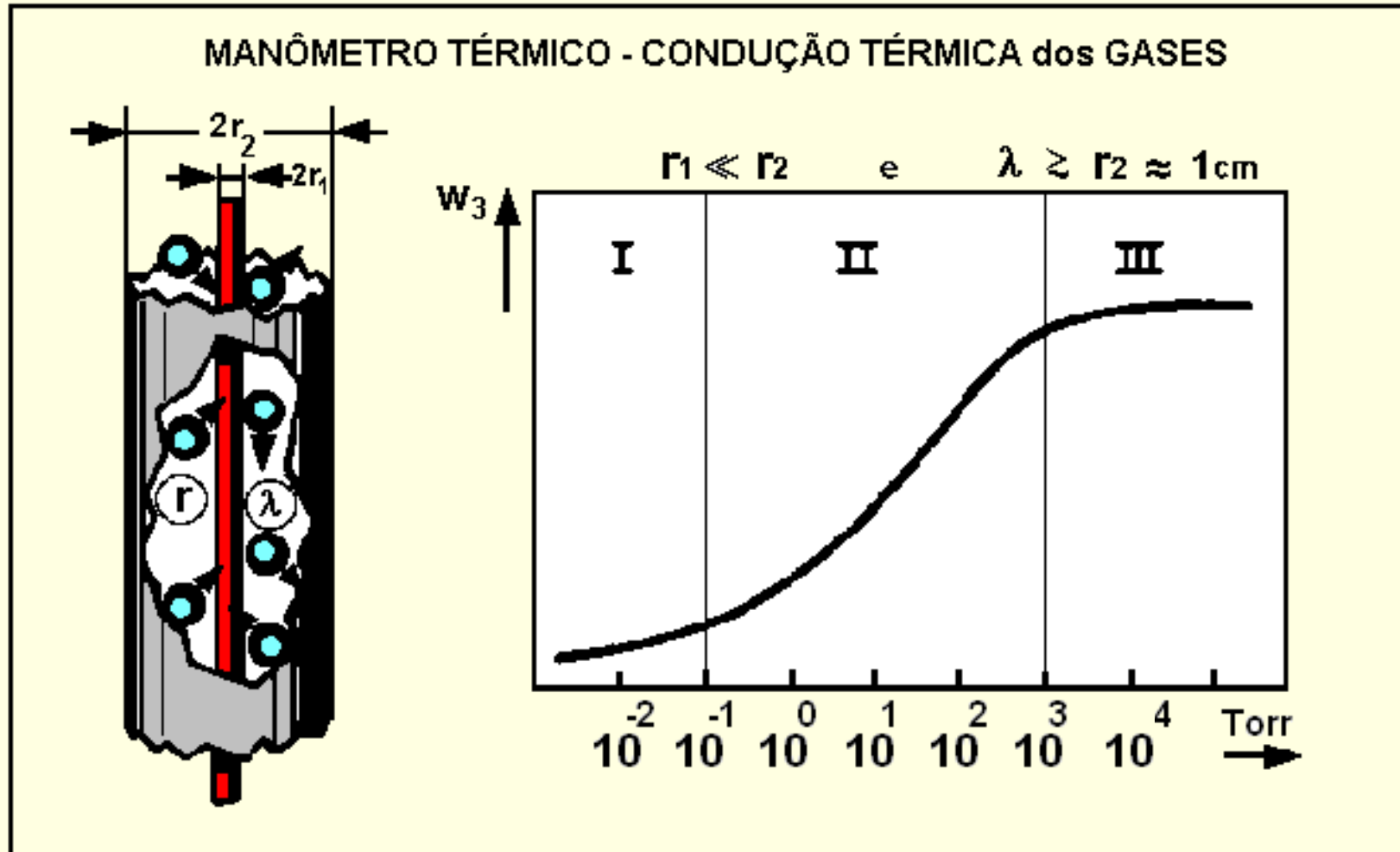
$$\text{Coeficiente de acomodação : } \alpha = \frac{T_r - T_i}{T_s - T_i}$$

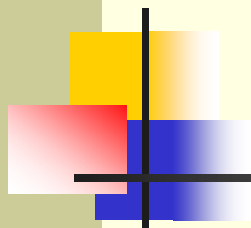


MEDIDOR PIRANI



MEDIDOR PIRANI

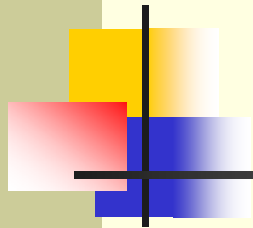




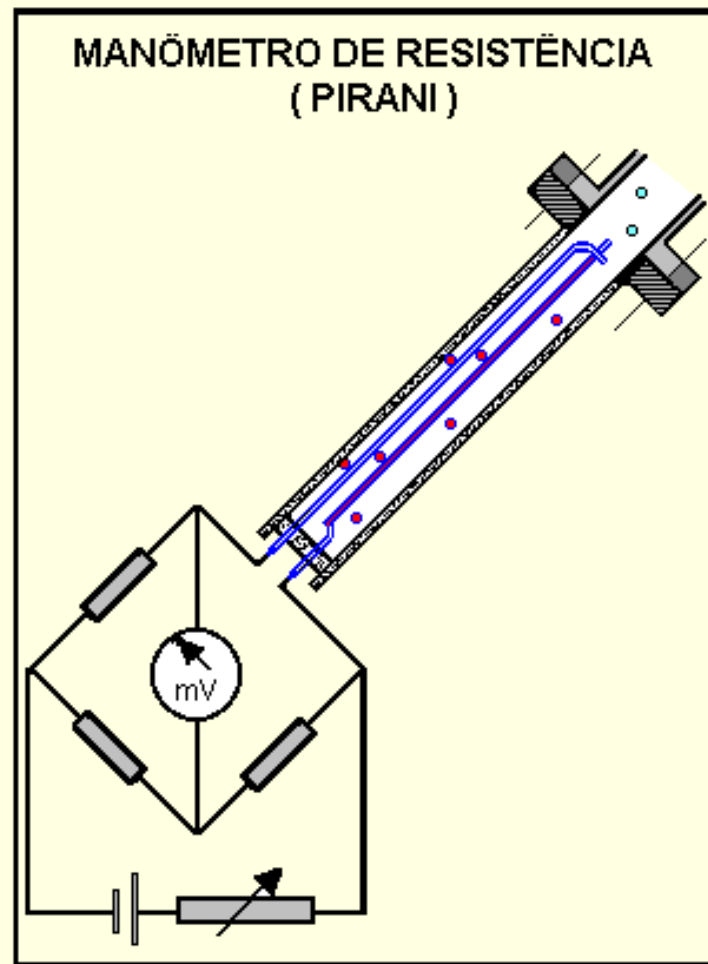
MEDIDOR PIRANI

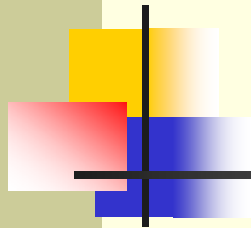
COEFICIENTE DE ACOMODAÇÃO

GÁS	SUPERFÍCIE				
	W	Pt		Ni	Fe
		Normal	Preta		
He	0.016	--	--	--	--
Ne	--	--	--	0.82	0.40
Ar	0.85	0.89	--	0.93	--
Kr	--	0.69	--	--	--
H ₂	0.36	0.28	0.71	0.29	--
N ₂	0.87	0.81	--	0.82	--
O ₂	0.90	0.85	0.95	0.86	--
CO ₂	--	--	0.97	--	--
Hg	0.95	--	--	--	--



MEDIDOR PIRANI

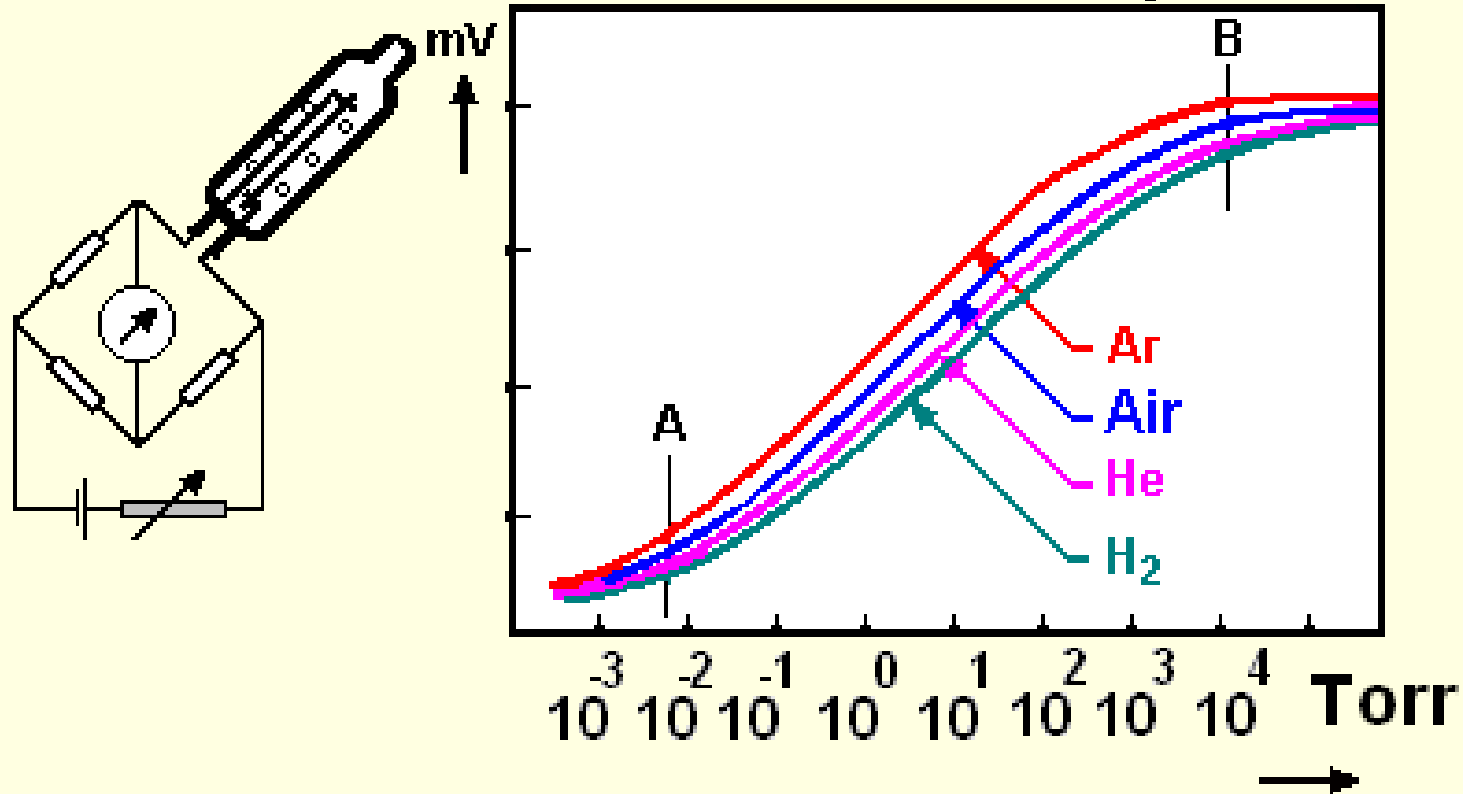




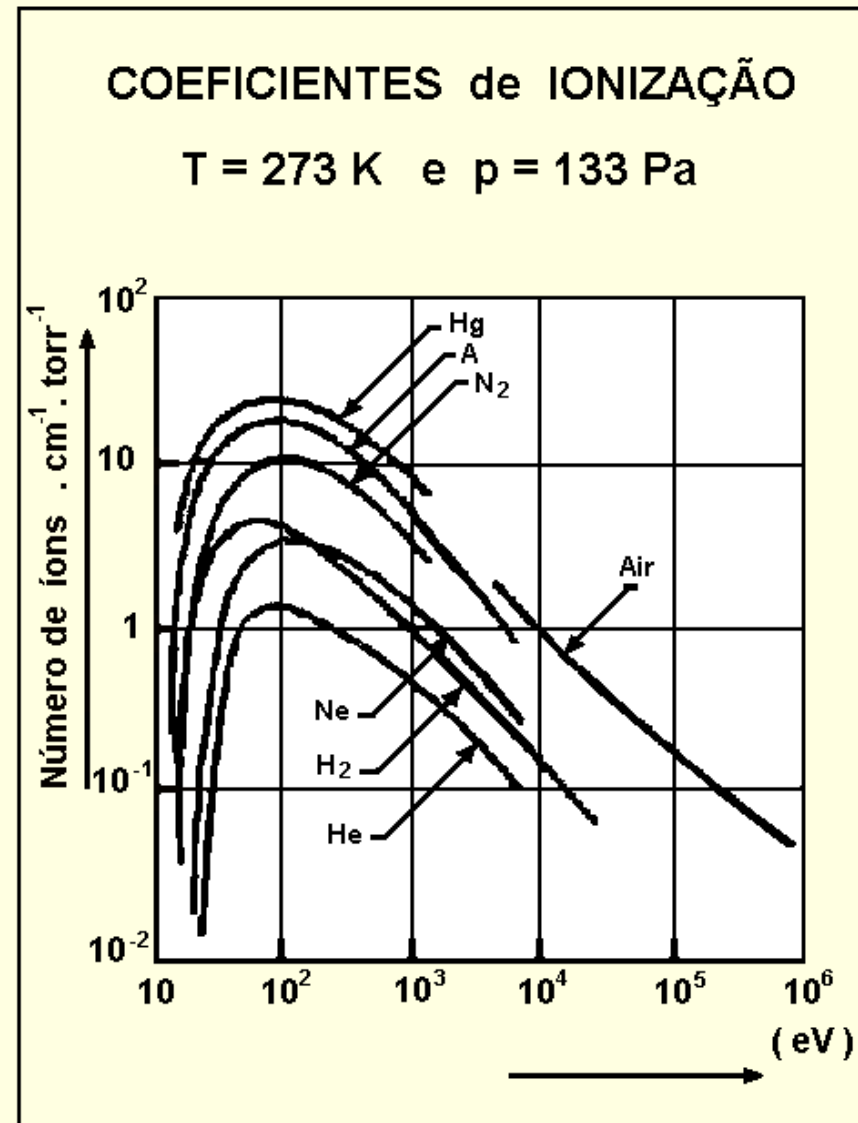
MEDIDOR PIRANI

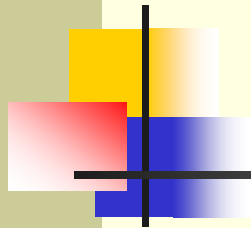
MANÔMETRO DE RESISTÊNCIA (PIRANI)

Curva de Calibração



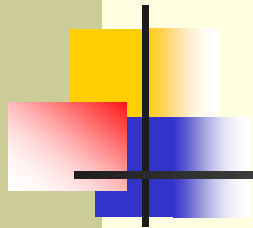
MEDIDOR DE IONIZAÇÃO



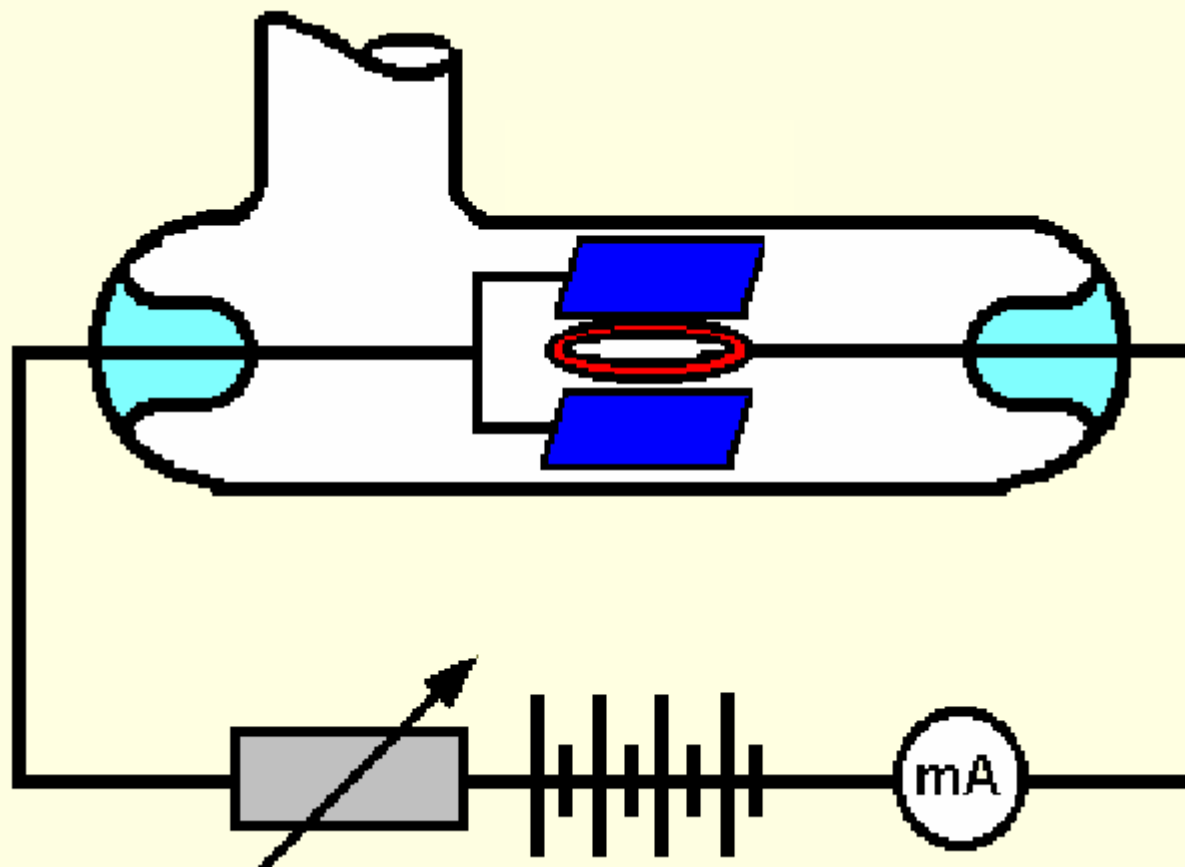


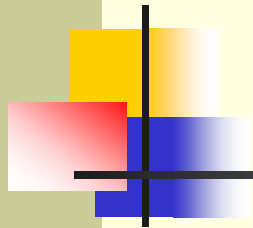
MEDIDOR PENNING



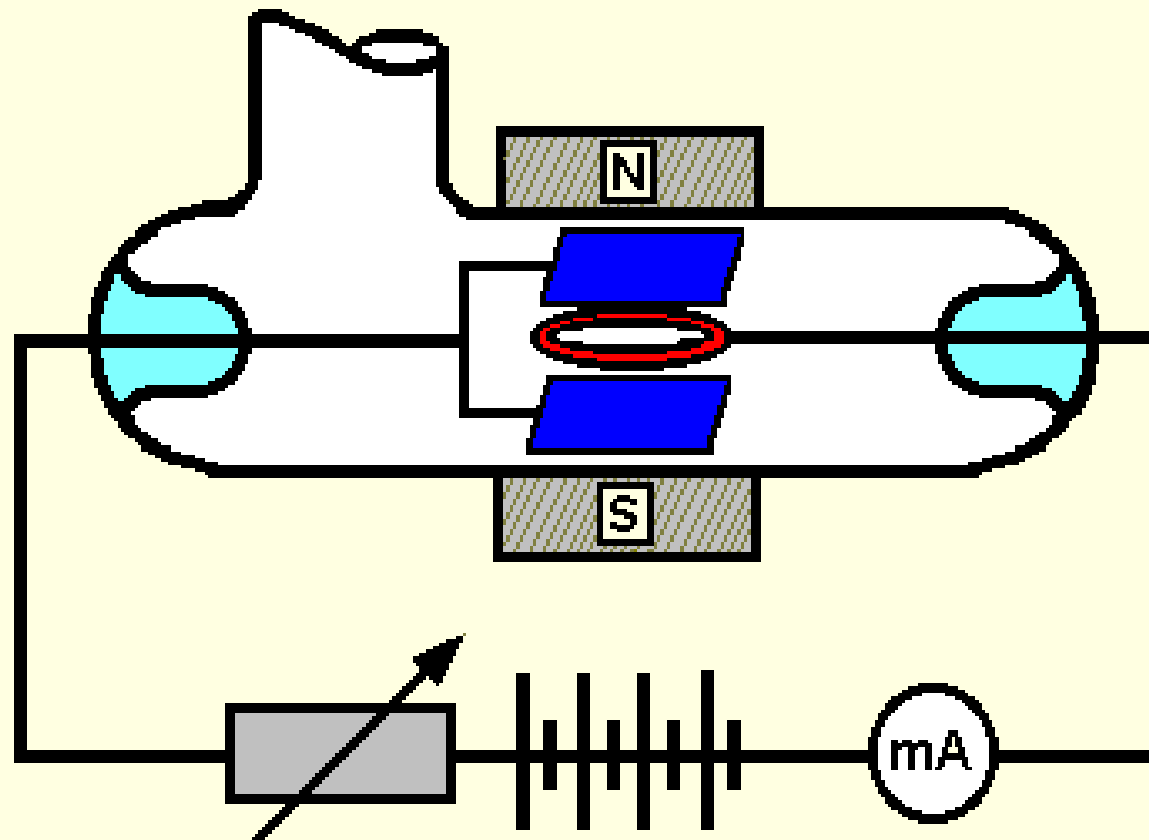


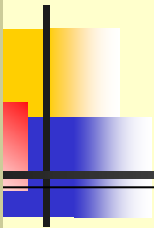
MEDIDOR PENNING





MEDIDOR PENNING





MEDIDOR DE IONIZAÇÃO



MEDIDOR DE IONIZAÇÃO

