Materiais Elétricos e Magnéticos para Engenharia

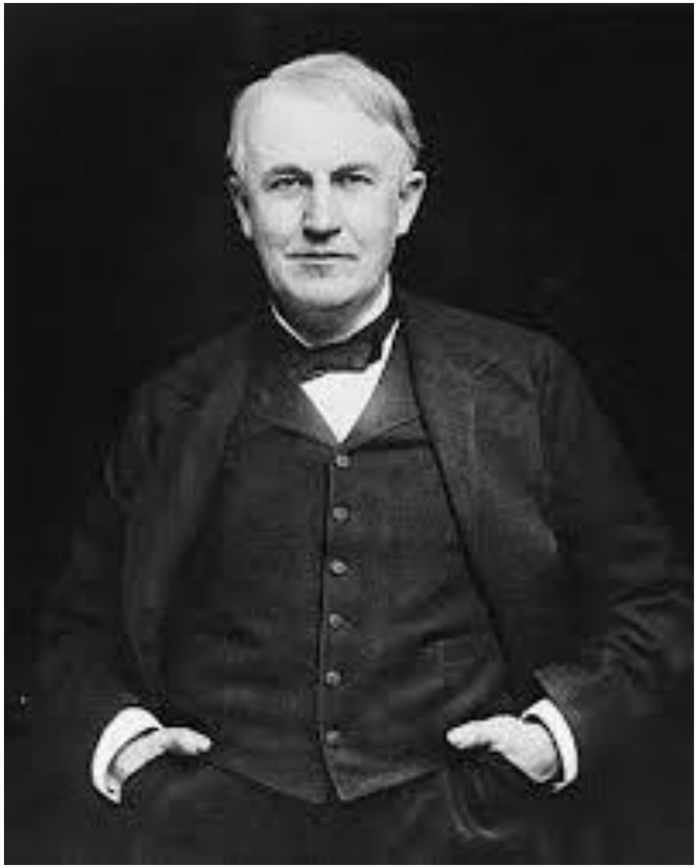
Professor: Marcus V. Batistuta

Laboratório #2

Lâmpada Elétrica de Filamento

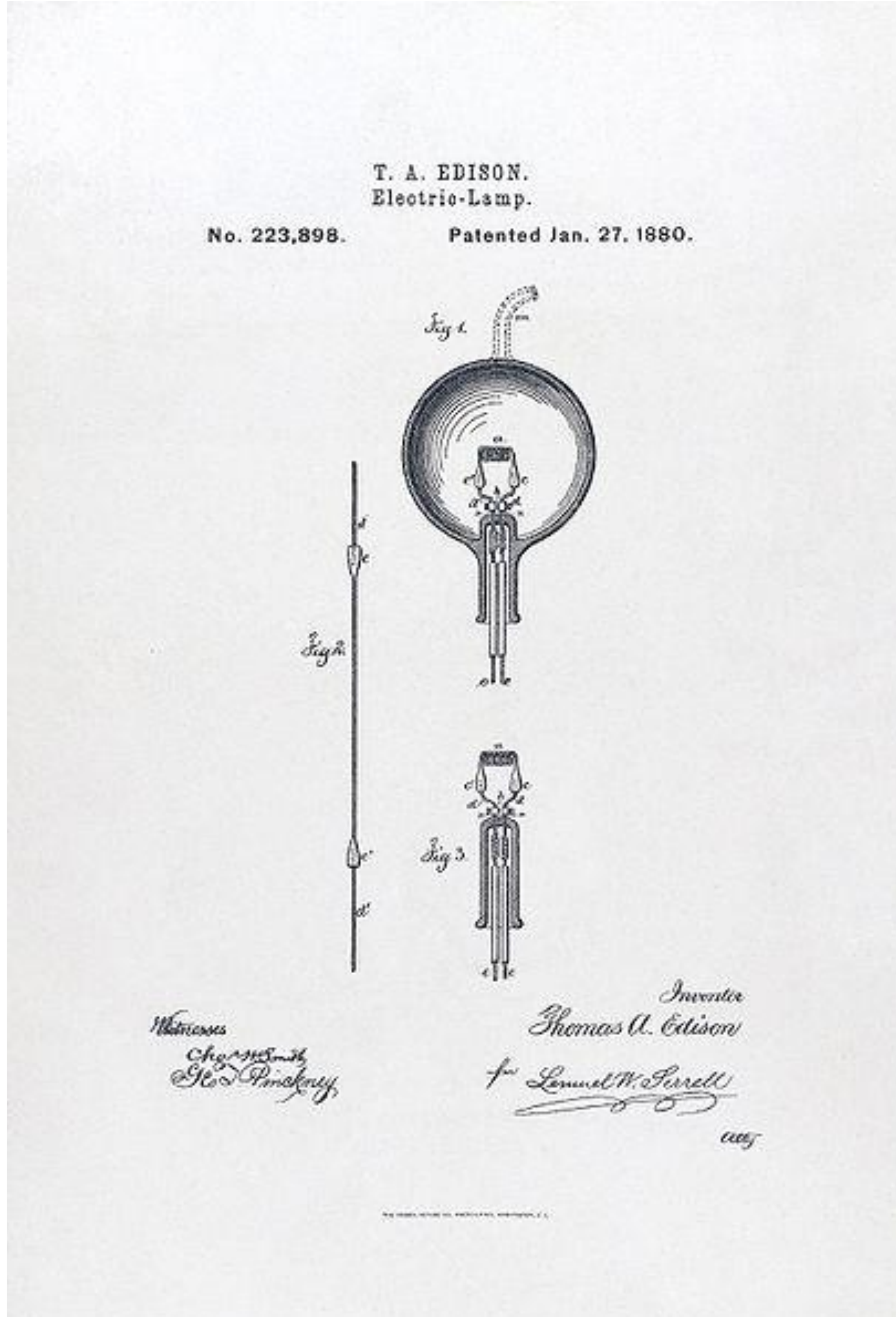
1º Semestre de 2018

FGA - Universidade de Brasília

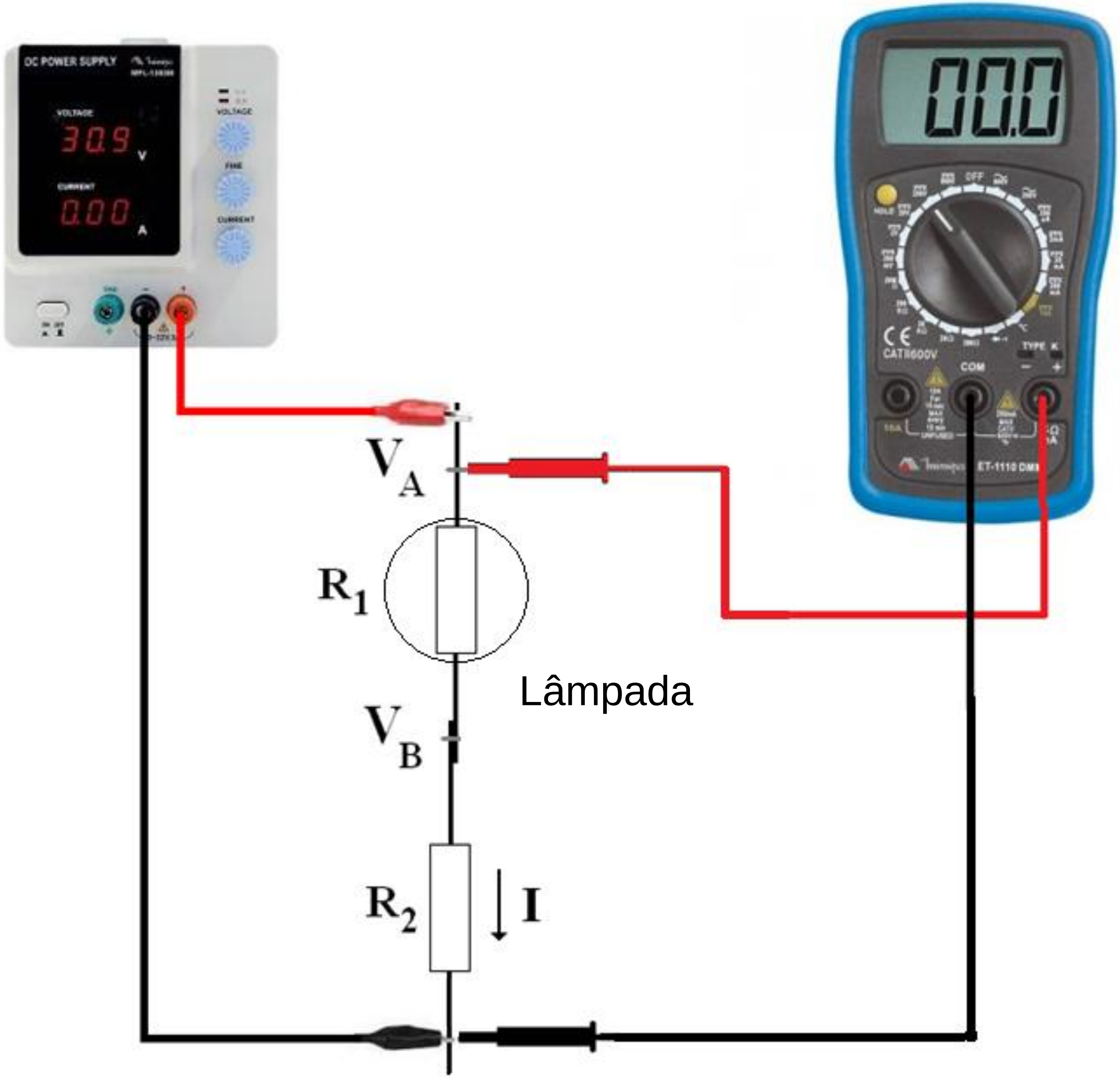


Thomas A. Edison
1847-1931

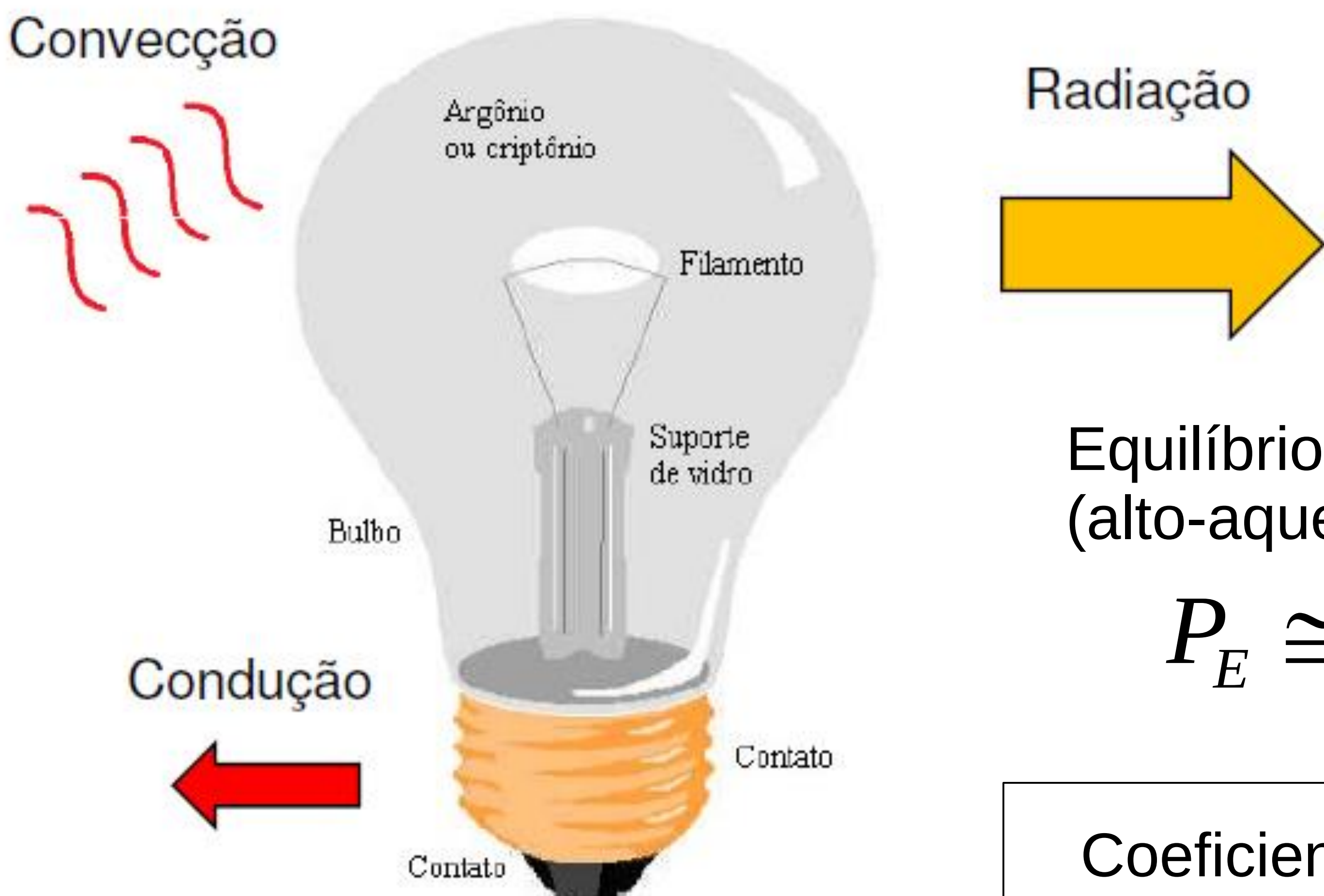
22 Outubro de 1879


T. A. EDISON.
Electric-Lamp.
No. 223,898.
Patented Jan. 27. 1880.
Fig. 1.
Fig. 2.
Fig. 3.
Witnesses
Inventor
Thomas A. Edison
Lemuel W. Serrell

Circuito de Medidas



Lâmpada Elétrica



Equilíbrio Térmico
(alto-aquecimento)

$$P_E \cong P_R$$

Coeficiente Térmico

$$\alpha_T = \frac{1}{R(T)} \left. \frac{dR}{dT} \right|_T$$

$$P_E = IV = \frac{V^2}{R(T)} = I^2 R(T)$$

Radiação de Corpo Negro

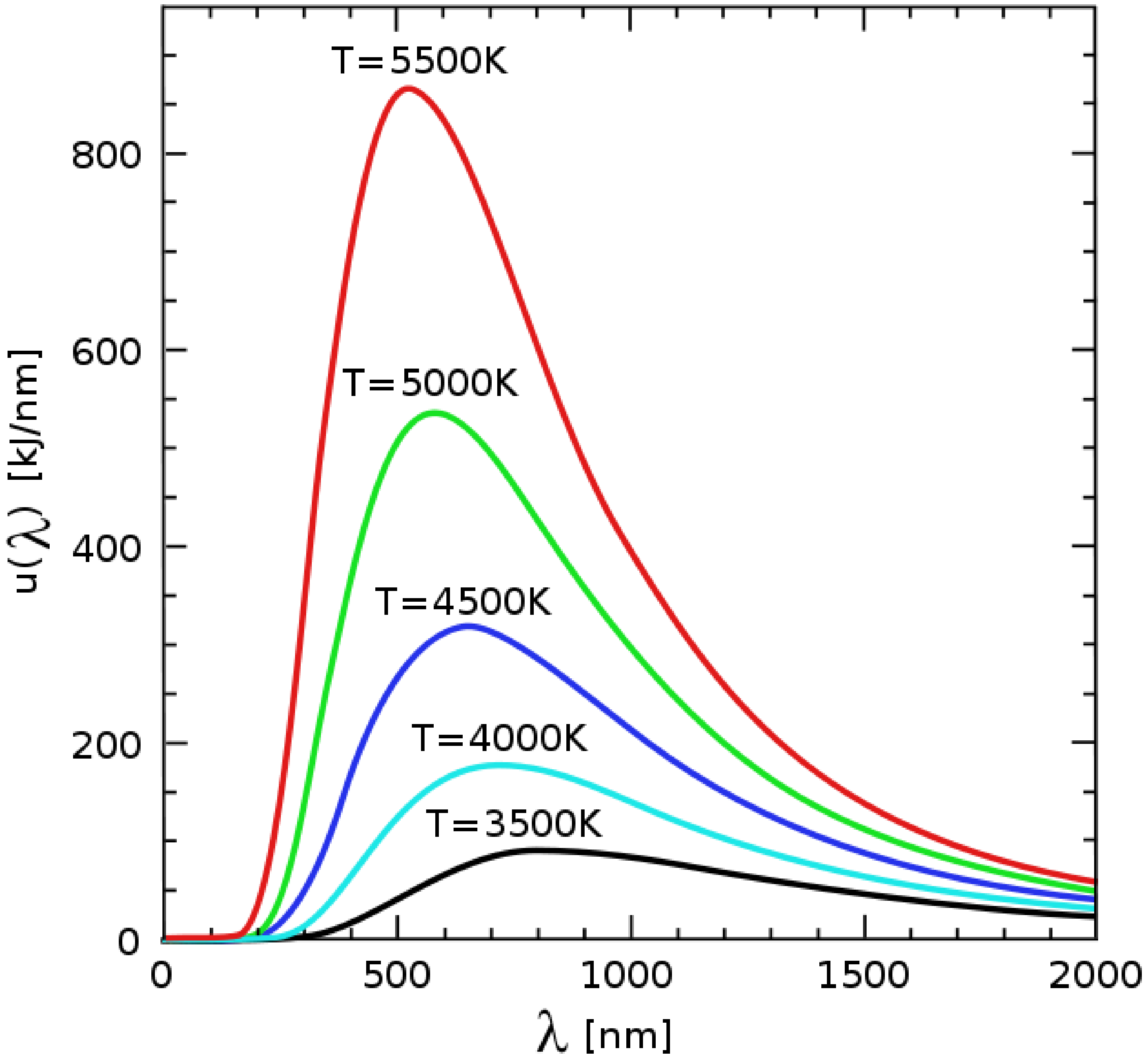
$$\left.\begin{aligned}
B(\upsilon,T) &= \frac{2h\upsilon^3}{c^2}\frac{1}{e^{\frac{h\upsilon}{kT}}-1}\left[\frac{W.sr^{-1}m^{-2}}{Hz}\right] \\
B(\lambda,T) &= \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda kT}}-1}\left[\frac{W.sr^{-1}.m^{-2}}{m}\right]
\end{aligned}\right\} \text{Lei de Planck}$$

$$P_R = A\varepsilon\sigma T^4$$ [W] Lei de Stefan-Boltzmann

$\sigma = 5.67 \times 10{-}8$ [W m^{-2} K^{-4}]

$$\varepsilon \approx 1$$ Emissividade

Radiação de Corpo Negro



Radiação de Filamento

Ponto de Máximo: $$\frac{dB(\lambda,T)}{d\lambda}=0$$

$$\lambda_{\max}T = 2897{,}756 \ [\mu\text{m.K}]$$

Temperatura Ideal (Centro da Banda Visível):

$$\lambda_{\max} = \frac{0{,}7+0{,}4}{2} = 0{,}55 \ [\mu\text{m}]$$

$$T = \frac{2897{,}756}{0{,}55} = 5268{,}6473 \ [\text{K}]$$

Ponto de fusão do tungstênio = 3695 K
Ponto de Sublimação do Carbono = 3915 K

Olho Humano

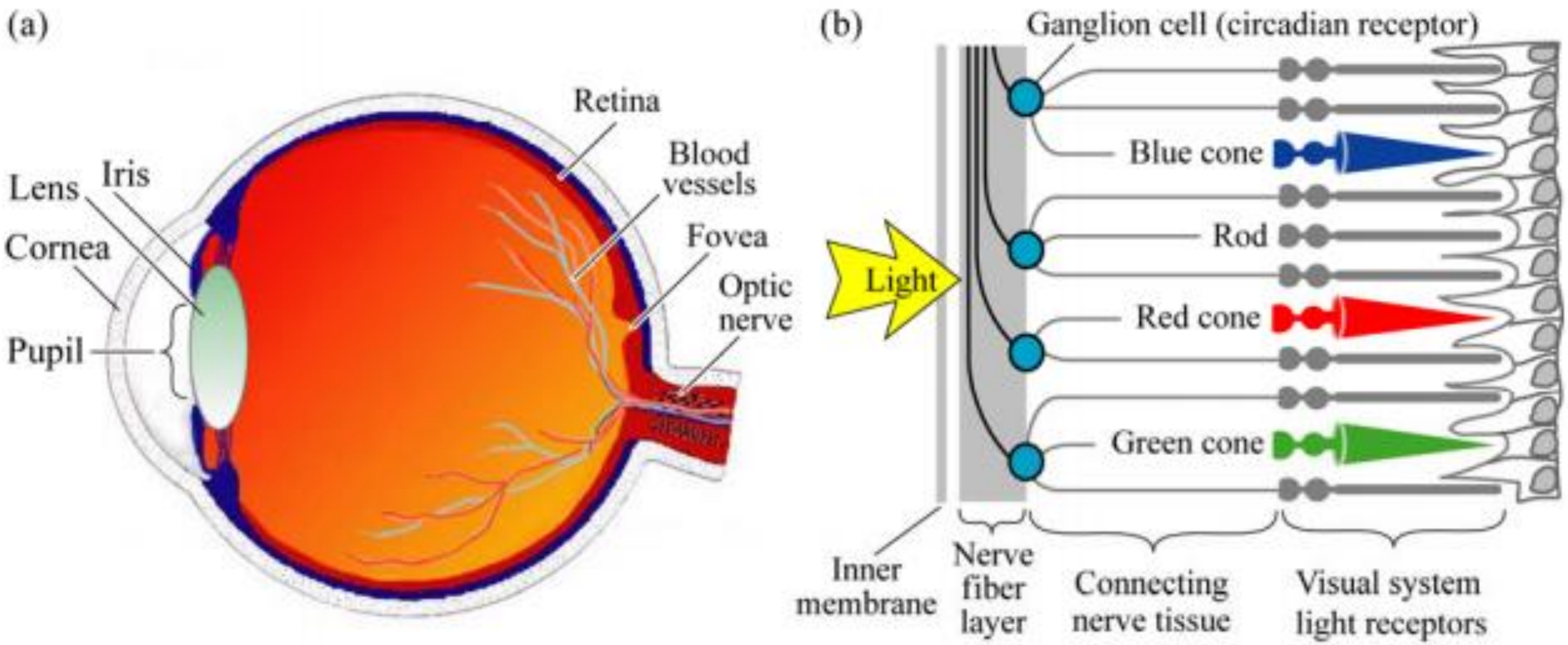
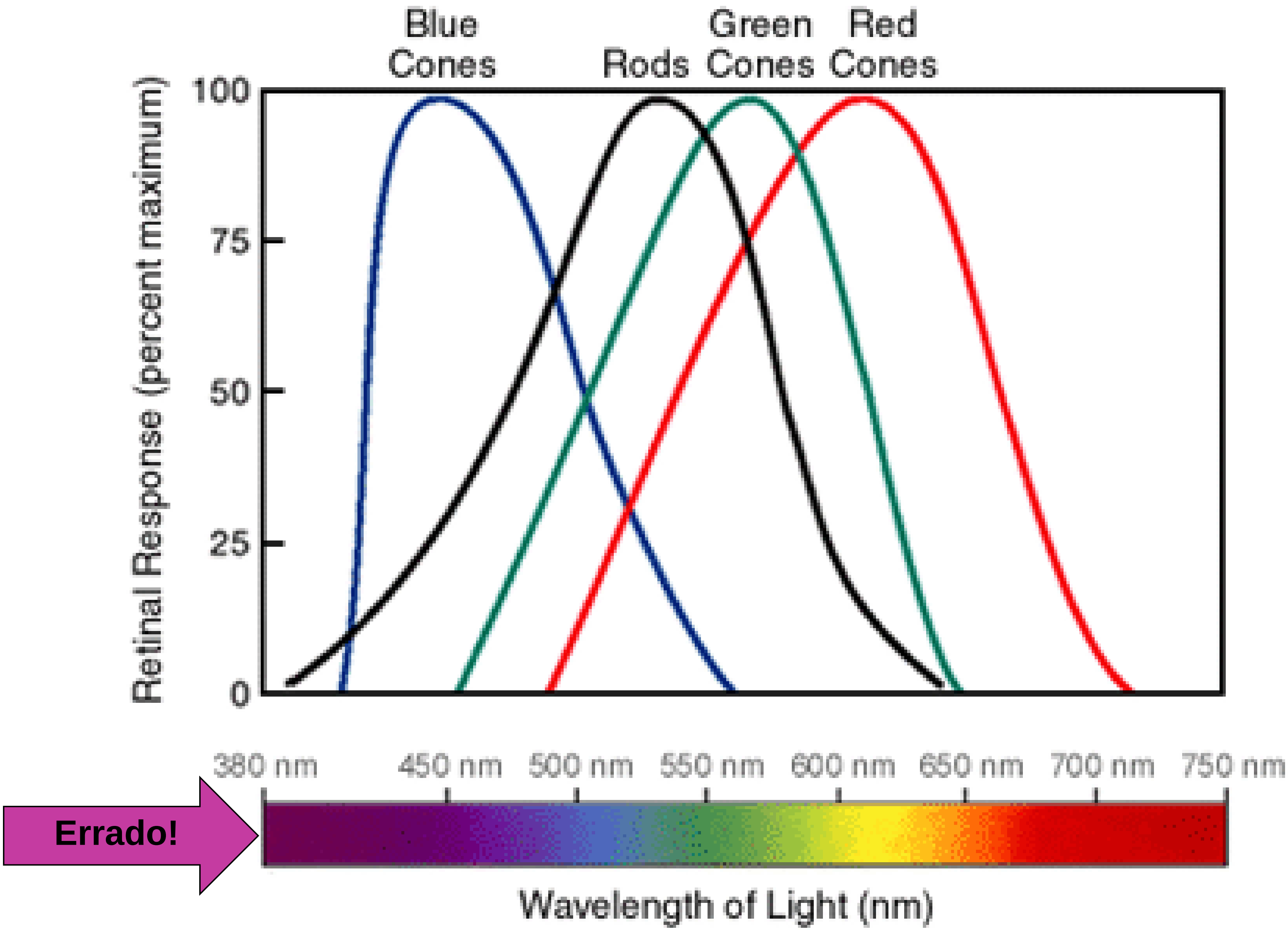


Fig. 16.1. (a) Cross section through a human eye. (b) Schematic view of the retina including rod and cone light receptors (adapted from Encyclopedia Britannica, 1994).

https://www.ecse.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/Sample-Chapter.pdf

Sensibilidade da Visão



Espectro de Sensibilidade do Olho Humano

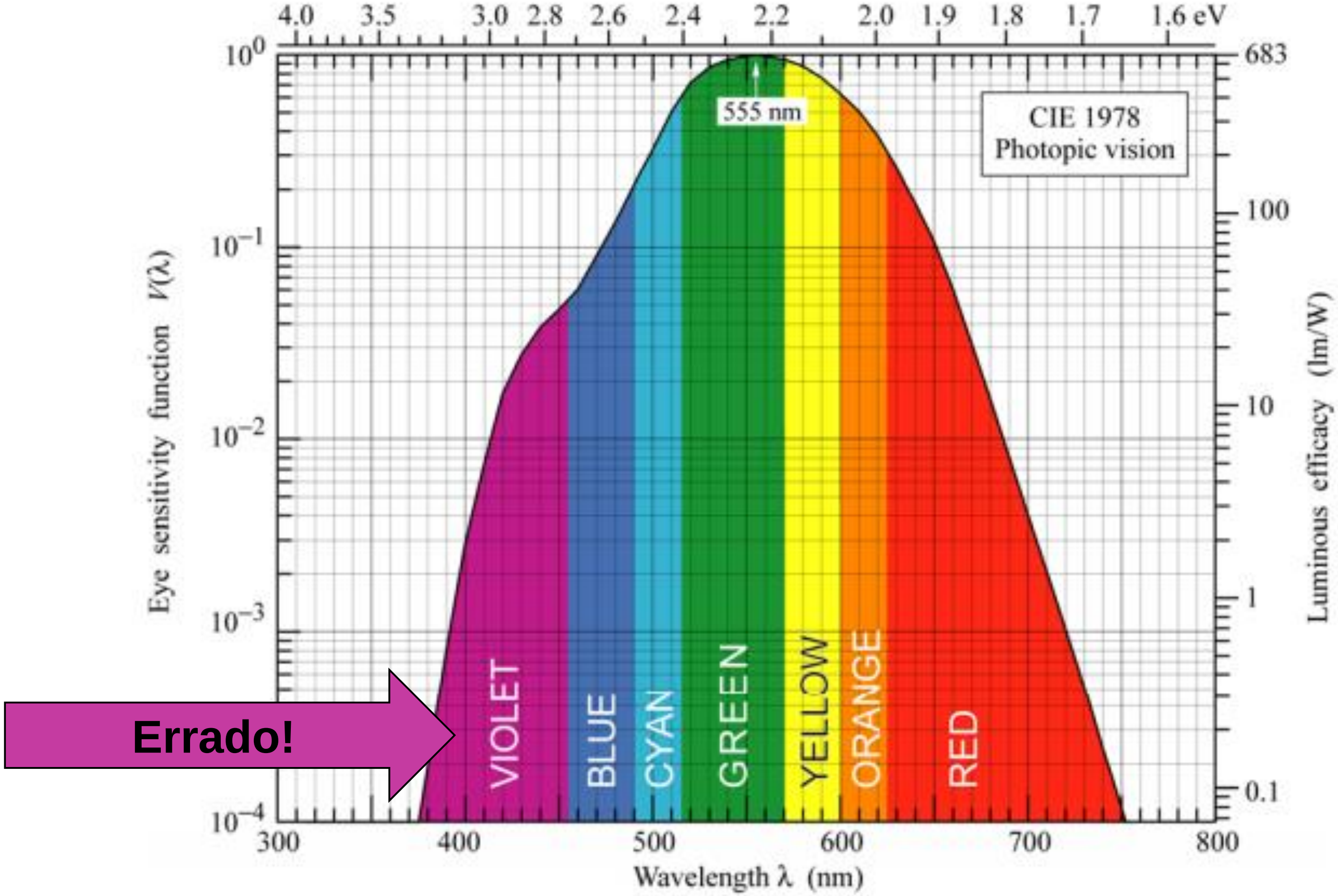
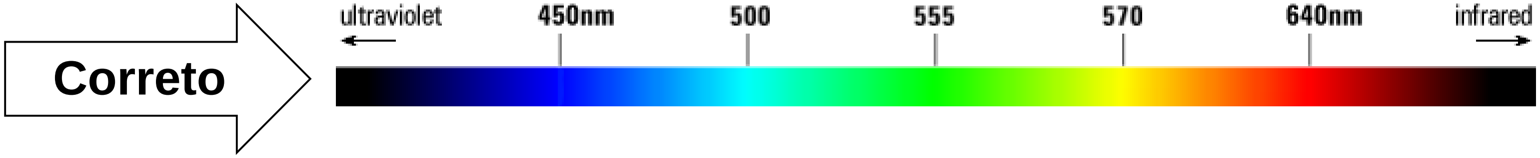
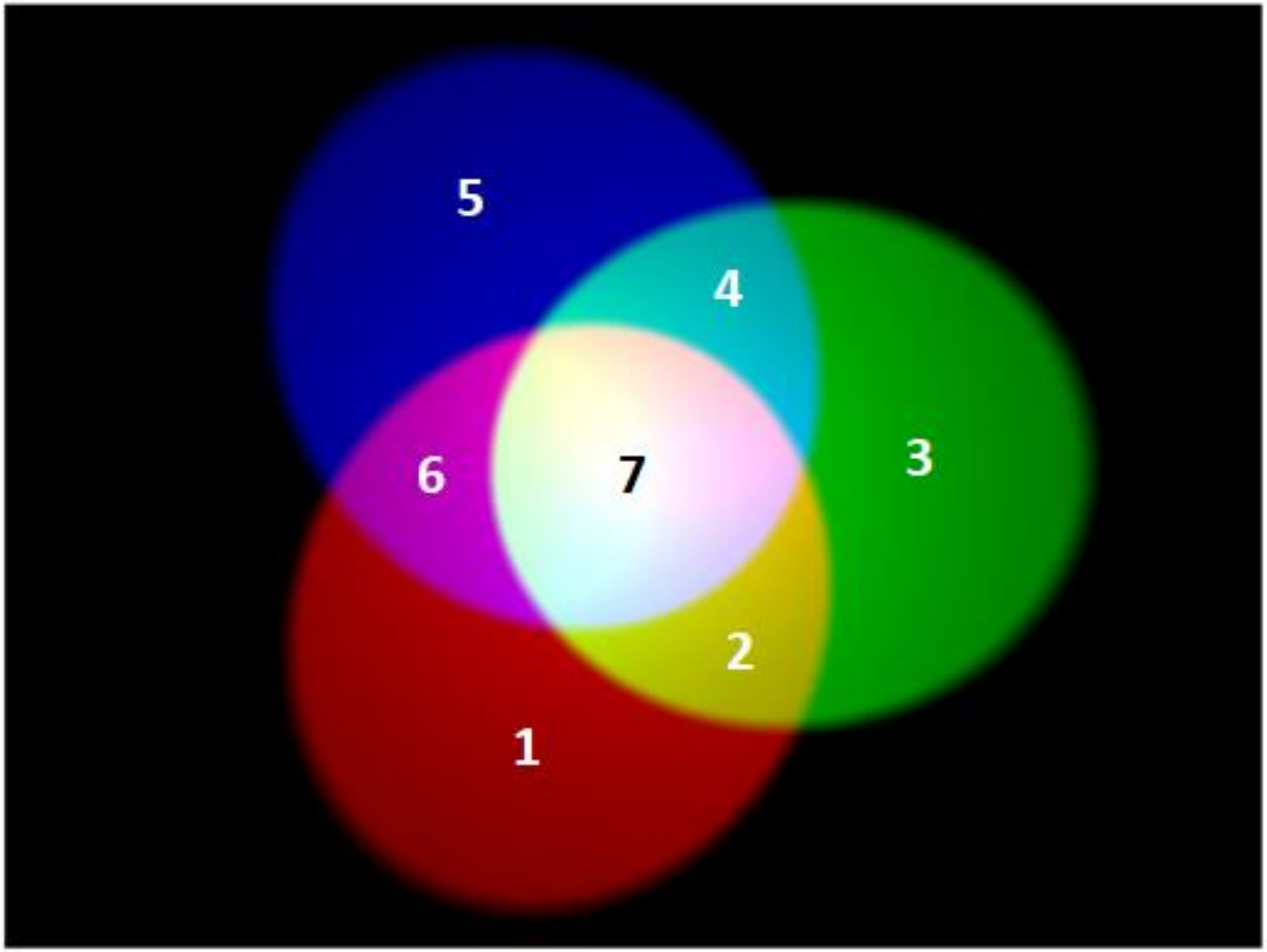


Fig. 16.7. Eye sensitivity function, $V(\lambda)$, (left-hand ordinate) and luminous efficacy, measured in lumens per watt of optical power (right-hand ordinate). $V(\lambda)$ is maximum at 555 nm (after 1978 CIE data).

https://www.ecse.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/Sample-Chapter.pdf

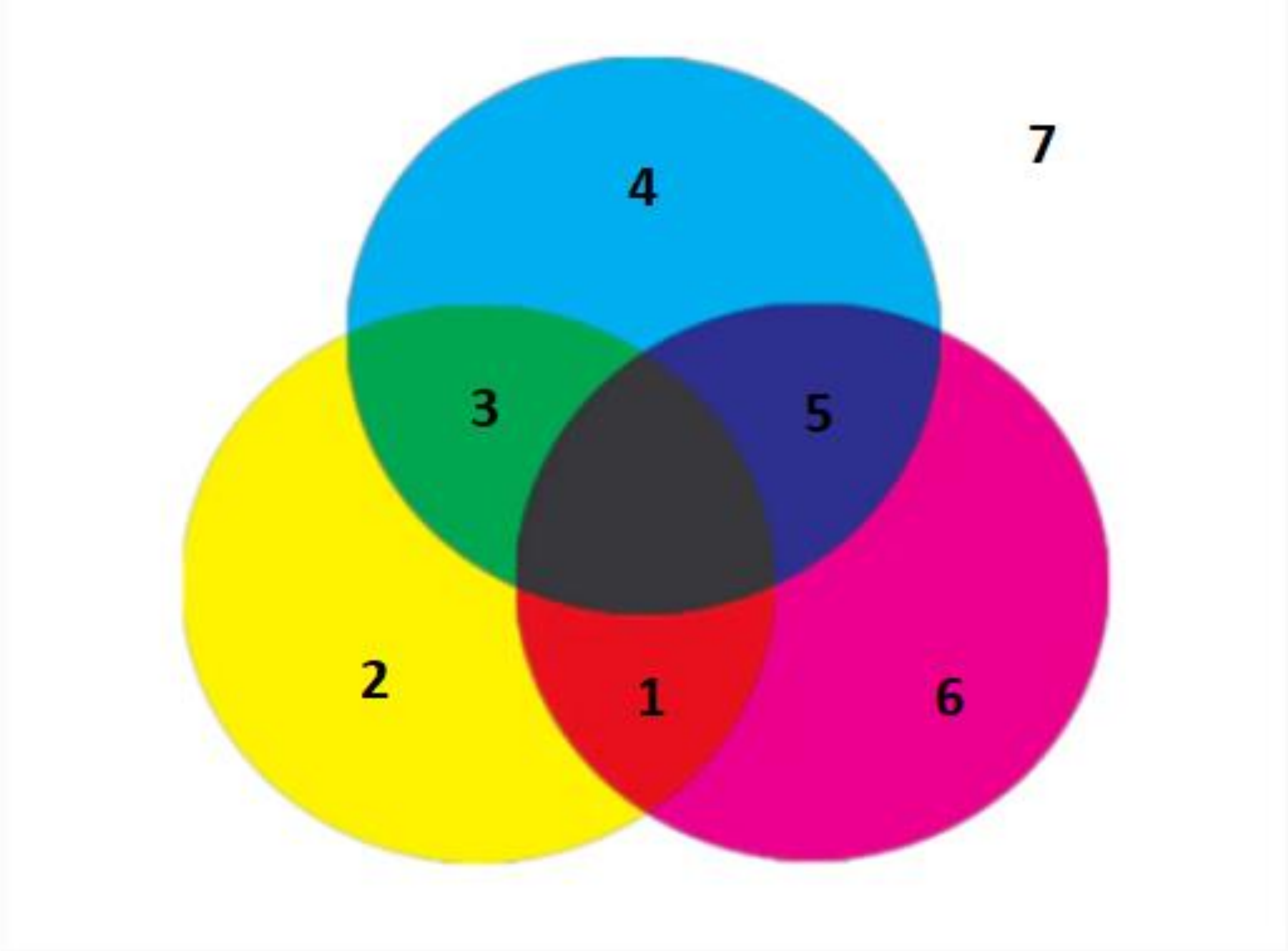


Processo Aditivo



Additive color mixing. If you (like me) have a hard time wrapping your head around how red and green mix together to make yellow, watch this YouTube video.

Processo Subtrativo



Subtractive color mixing is pretty close to the paint mixing we did in grade school. This video does a great job visualizing the "subtractive" part of it.

7 Cores + Preto (Nenhuma Cor) ou Branco (Todas as Cores)

Aditivo **Subtrativo**

N = 3 => R,G,B (Retina, 1 bit por cor)

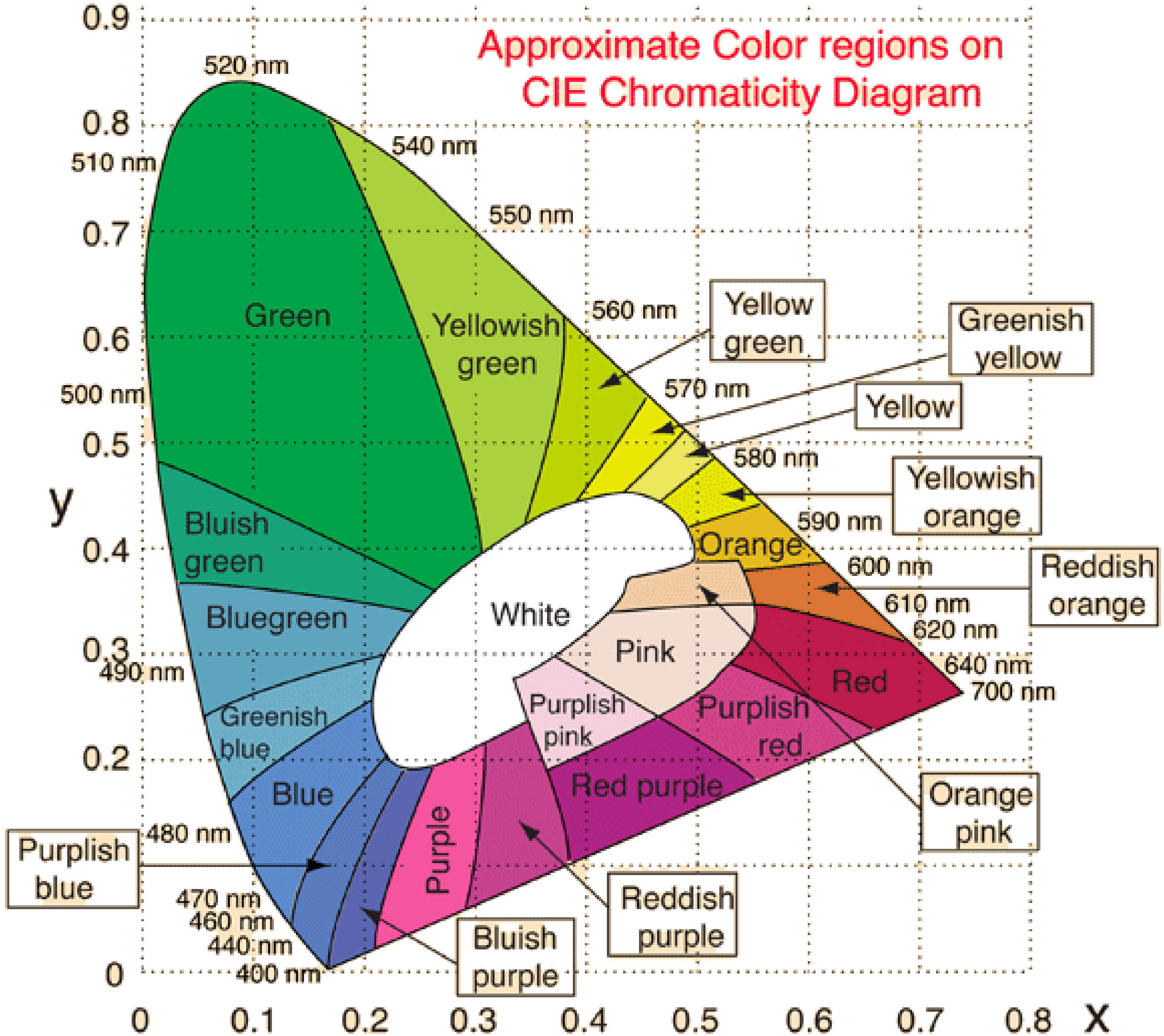
Ligado/Desligado

$$2^3 = 8$$

Processo Aditivo:
(2 níveis - 0 ou 1)

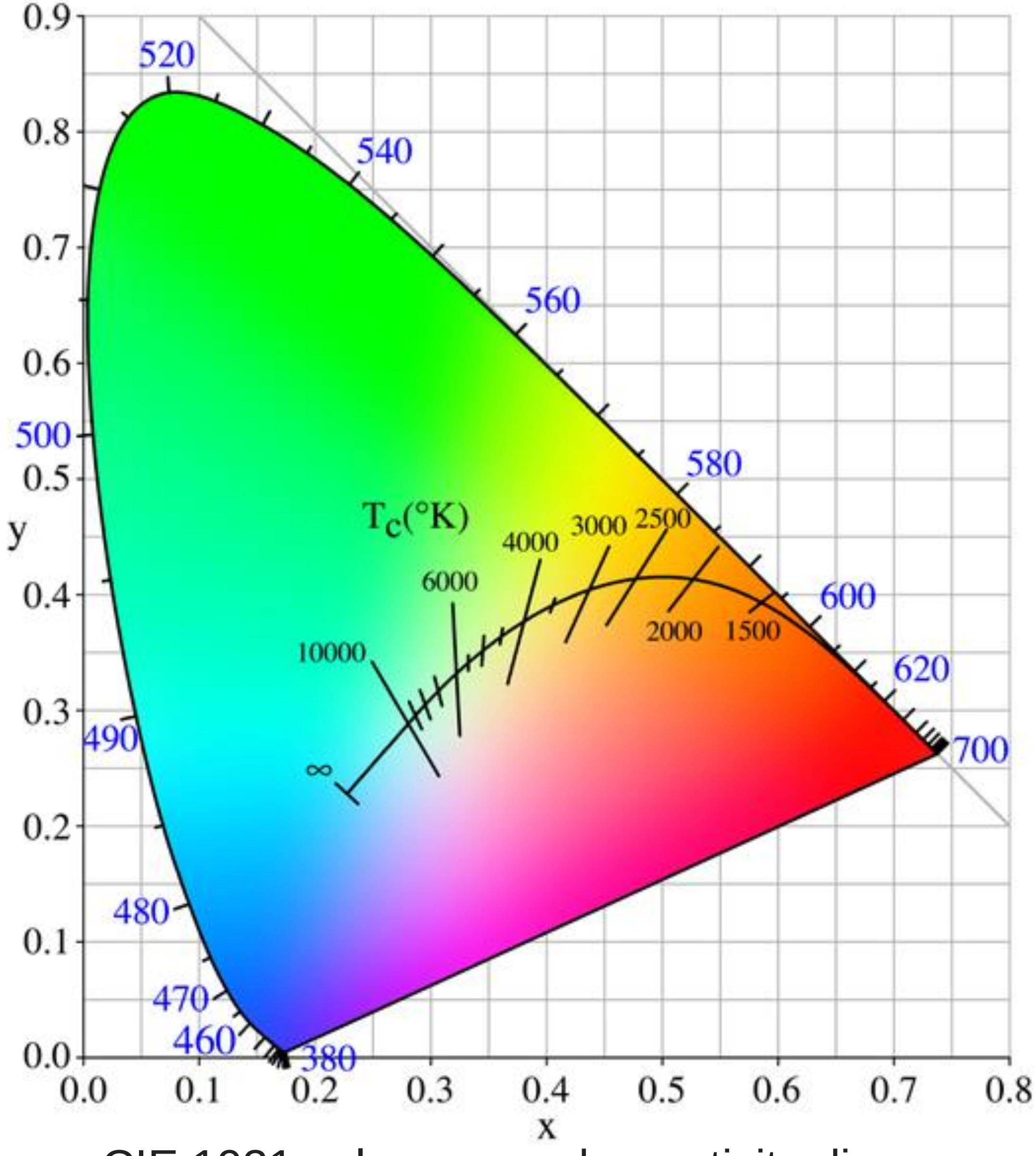
R	G	B		#
0	0	0	Preto	0
1	0	0	Vermelho	1
1	1	0	Amarelo	2
0	1	0	Verde	3
0	1	1	Ciano	4
0	0	1	Azul	5
1	0	1	Violeta	6
1	1	1	Branco	7

Não existe na sequência do espectro!



http://hyperphysics.phy-astr.gsu.edu/hbase/vision/cie.html

Radiação de Corpo Negro

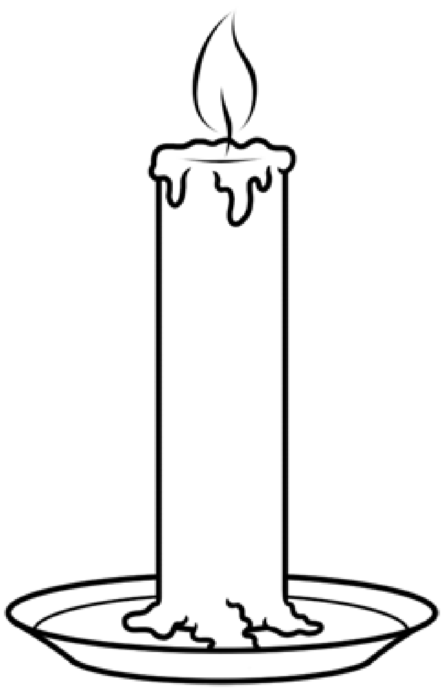


CIE 1931 color space chromaticity diagram

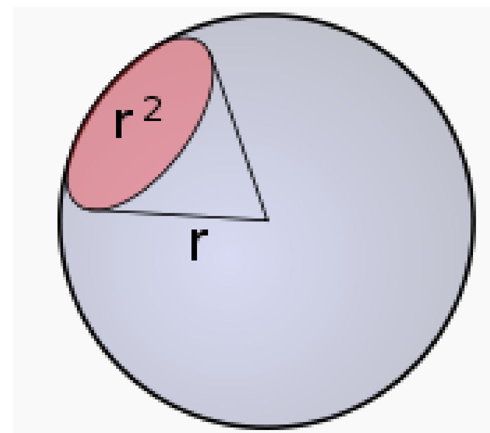
Ponto de fusão do tungstênio = 3695 K
Ponto de Sublimação do Carbono = 3915 K

Candela e Lúmen

A candela é a intensidade luminosa, numa dada direção, de uma fonte que emite uma radiação monocromática de frequência 540 x 10^{12} hertz e que tem uma intensidade radiante nessa direção de $\frac{1}{683}$ watt por esferorradiano (sr).



Vela: ~1 candela



1 cd·1 sr = 1 lm

Isotrópica: 1 candela = 4π lúmens

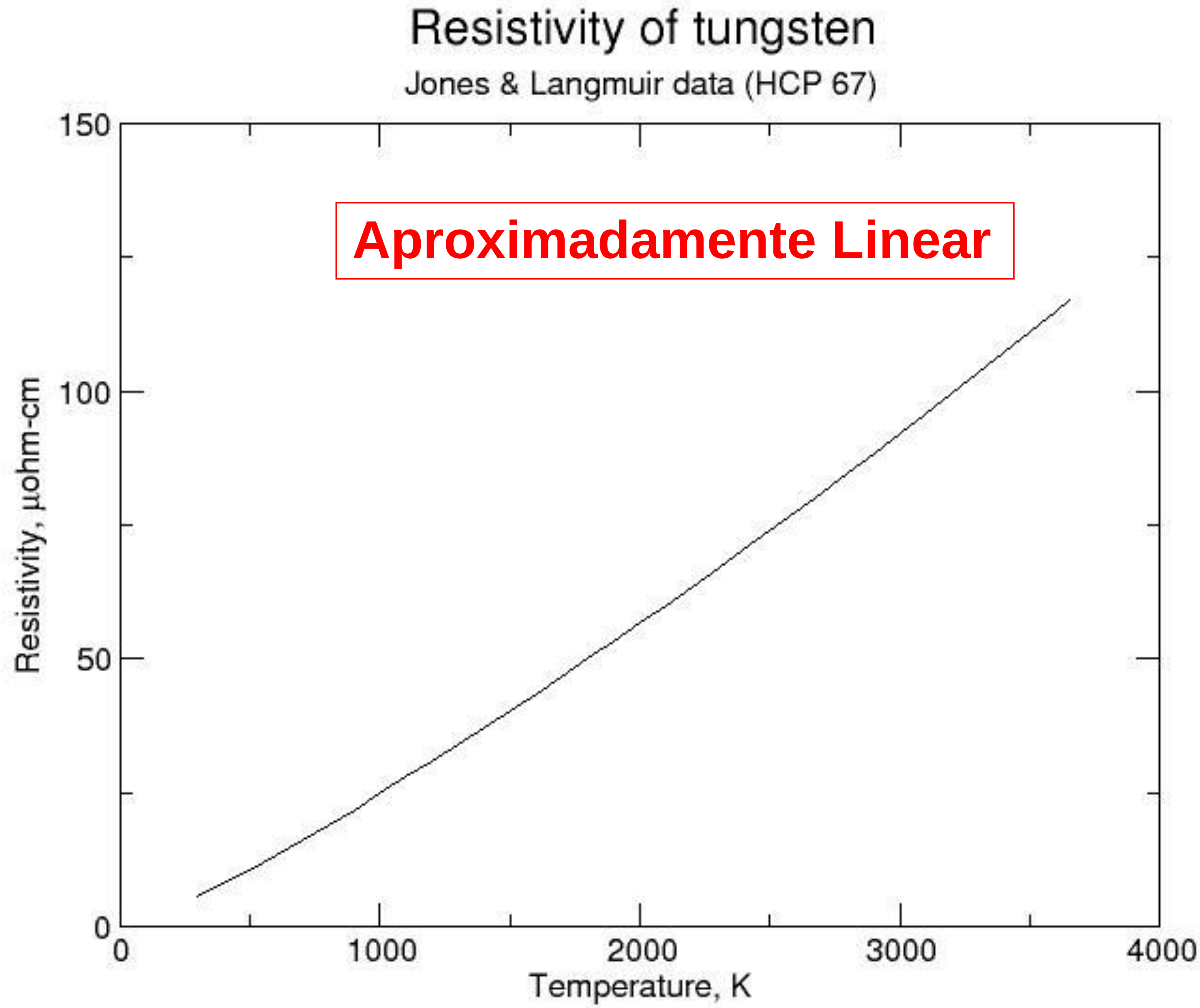
Esfera: A = $4\pi r^2$

Eficiência e Eficácia

Type	Overall luminous efficiency	Overall luminous efficacy (lm/W)
40 W tungsten incandescent	1.9%	12.6[1]
60 W tungsten incandescent	2.1%	14.5[1]
100 W tungsten incandescent	2.6%	17.5[1]
glass halogen	2.3%	16
quartz halogen	3.5%	24
photographic and projection lamps with very high filament temperatures and short lifetimes	5.1%	35[53]
ideal black-body radiator at 4000 K (or a class K star like Arcturus)	7.0%	47.5
ideal black-body radiator at 7000 K (or a class F star like Procyon)	14%	95
ideal monochromatic 555 nm (green) source	100%	683[54]

Resistividade do Tungstênio

$$R = \rho \frac{L}{A}$$



Modelo para a Lâmpada Elétrica

$$V = RI \qquad R(T) = \rho(T)\frac{L}{A} \qquad \rho(T) \cong K_T T$$

Aprox. Linear

$$R(T) = K_T T \frac{L}{A} = K'_T\, T$$

$$P_E = IV = \frac{V^2}{R(T)} = I^2 R(T) = \frac{V^2}{K'_T\, T} = I^2 K'_T\, T$$

$$P_E \cong P_R \qquad P_R = A\varepsilon\sigma T^4$$

$$I^2 K'_T\, T \cong A\varepsilon\sigma T^4 \qquad \frac{V^2}{K'_T\, T} \cong A\varepsilon\sigma T^4$$

$$I^2 \cong \frac{A\varepsilon\sigma}{K'_T} T^3 \qquad V^2 \cong K'_T\, A\varepsilon\sigma T^5$$

$$I \cong \sqrt{\frac{A\varepsilon\sigma}{K'_T}} T^{\frac{3}{2}} \qquad V \cong \sqrt{K'_T\, A\varepsilon\sigma} T^{\frac{5}{2}}$$

$$I \cong K_I T^{\frac{3}{2}} \qquad V \cong K_V T^{\frac{5}{2}}$$

Verificando: $$R(T) = \frac{V}{I} \cong \frac{K_V T^{\frac{5}{2}}}{K_I T^{\frac{3}{2}}} = K'_T\, T$$ **Aprox. Linear**

$$I \cong K_I T^{\frac{3}{2}} \qquad V \cong K_V T^{\frac{5}{2}}$$

$$V^{\frac{2}{5}} \cong (K_V)^{\frac{2}{5}} T \qquad T = \frac{V^{\frac{2}{5}}}{(K_V)^{\frac{2}{5}}}$$

$$I \cong K_I \left(\frac{V^{\frac{2}{5}}}{(K_V)^{\frac{2}{5}}} \right)^{\frac{3}{2}} \qquad I \cong \left(\frac{K_I}{(K_V)^{\frac{3}{5}}} \right) V^{\frac{3}{5}}$$

$$\boxed{I \cong K V^{\frac{3}{5}}}$$

Não-linear