WS 6.2 Effective diode spacing in a triode

This Mathcad 14 worksheet is designed to accompany the author's book "Microwave and RF Vacuum Electronic Power Sources", Cambridge University Press (2018). The section, equation, and figure numbers refer to the corresponding sections, equations, and figures in the book. Data input fields are highlighted in yellow and output fields are highlighted in green.

Section 6.4

The electric field at the cathode can be interpreted as the ratio of an effective voltage to an effective spacing

$$E_c = -\frac{V_g + D\cdot V_a}{d_1 + D\cdot(d_1 + d_2)} = \frac{V_e}{d_e} \qquad E_c = -\frac{V_g + DV_a}{d_1 + (d_1 + d_2)D} \qquad d = \frac{d_e}{d_1}$$

Then the space-charge limited current density is assumed to be given by

$$J = K\cdot\frac{{V_e}^{1.5}}{{d_e}^2} \qquad P = \frac{K}{{d_1}^2}\cdot Pn \qquad J = P\cdot\left(V_g + D\cdot V_a\right)^{1.5}$$

The possibilities offered in the literature give different results for the Perveance

$$P1(D,x) := \frac{1}{[1+D\cdot(1+x)]^{2}}$$

$\boxed{\text{Equation 6.57 (Dow)}}$

$$P2(D,x) := \frac{1}{[1+D\cdot(1+x)]^{1.5}}$$

$\boxed{\text{Equation 6.58 (Bennett (b))}}$

$$P3(D,x) := \frac{\sqrt{1+D}}{[1+D\cdot(1+x)]^{2}}$$

$\boxed{\text{Equation 6.56 (Walker)}}$

Tellegen added a modification to account for space-charge

$$P4(D,x) := \frac{1}{\left[1+D\cdot\left(1+\frac{4}{3}\cdot x\right)\right]^{1.5}}$$

$\boxed{\text{Equation 6.59 (Tellegen)}}$

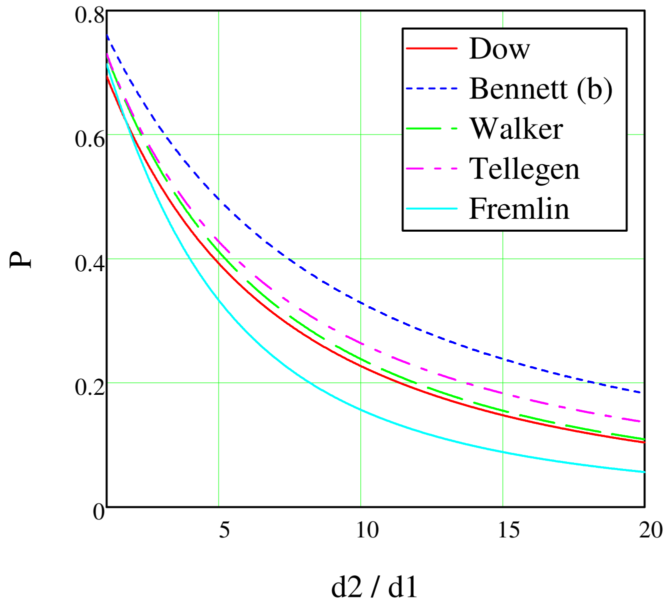
Fremlin calculated the perveance from a diode with the grid removed

$$P5(D,x) := \frac{1}{\left[1+D\cdot(1+x)^{\frac{4}{3}}\right]^{1.5}}$$

$\boxed{\text{Equation 6.60 (Fremlin)}}$

$D1 := 0.1$

$x1 := 10$ $\quad x = \dfrac{d_2}{d_1}$ $\quad x := -3, -2.9 .. 0 \quad D(x) := 10^x$



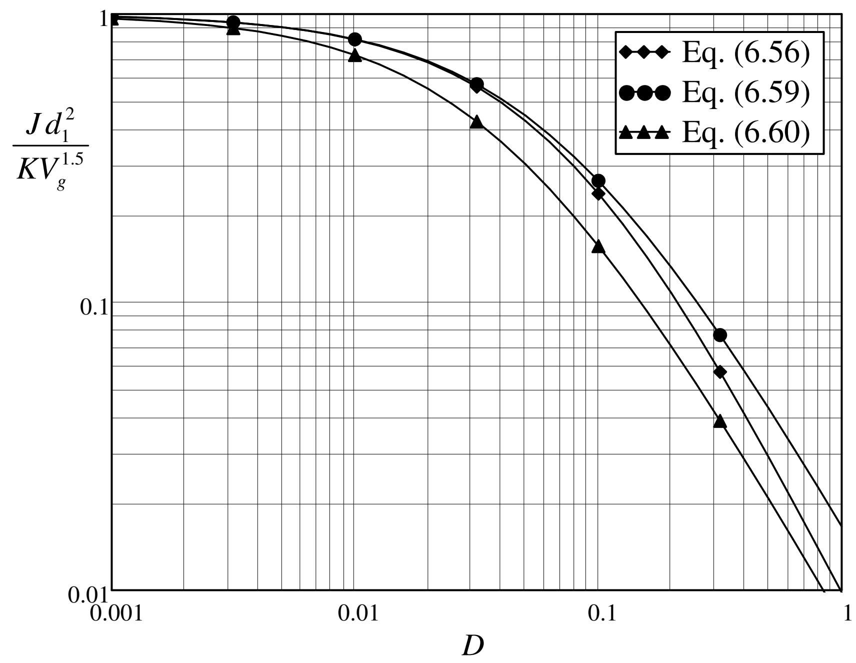
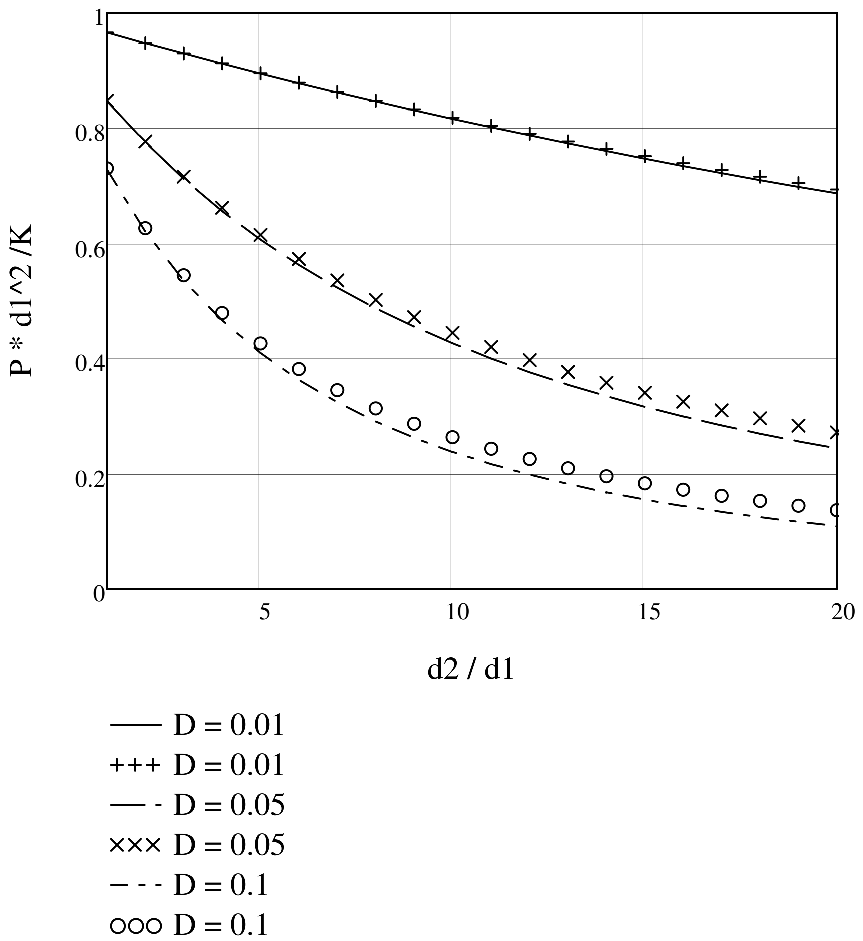


Figure 6.6

D1 := 0.01 D2 := 0.05 D3 := 0.1 x := 1 .. 20



Lines Walker

Symbols Tellegen

Calculation of Fremlin's fig.7 using Walker's formula

$a := 1.75\cdot mm$ $\quad d_1 := 1.7\cdot mm$ $\quad d_2 := 6.73\cdot mm - d_1$ $\quad d_2 = 5.03\cdot mm$ $\quad r := 0.0445\cdot mm$

$e\_m := 1.759\cdot 10^{11}\cdot C\cdot kg^{-1}$ $\quad \mu Perv := \mu A\cdot V^{-1.5}$

$V_a := 200\cdot V$

$K_1 := \frac{4}{9}\cdot\varepsilon_0\cdot\sqrt{2\cdot e\_m}$ $\quad K_1 = 2.334\cdot\mu Perv$

$D := \frac{-a}{2\cdot\pi\cdot d_2}\cdot\ln\left(2\cdot\sin\left(\frac{\pi\cdot r}{a}\right)\right)$ $\quad D = 0.102$ $\quad \frac{1}{D} = 9.841$

$$J_1(V_g, V_a) := K_1\cdot\frac{\sqrt{1 + D}\cdot\left(V_g + D\cdot V_a\right)^{\frac{3}{2}}}{\left[d_1 + D\cdot\left(d_1 + d_2\right)\right]^2}$$

Experimental data points from Fremlin's fig.7

$$Vg := \begin{pmatrix} -19.4 \\ -18.8 \\ -17.5 \\ -15.7 \\ -14.6 \\ -13.4 \\ -12.4 \\ -11.2 \\ -10.1 \\ -8.3 \\ -6.6 \\ -5.2 \\ -3.9 \\ -2.6 \\ -1.7 \\ -1.1 \\ -0.1 \end{pmatrix} \qquad Ja := \begin{pmatrix} 0.07 \\ 0.10 \\ 0.22 \\ 0.44 \\ 0.58 \\ 0.78 \\ 0.95 \\ 1.17 \\ 1.41 \\ 1.75 \\ 2.09 \\ 2.45 \\ 2.80 \\ 3.16 \\ 3.40 \\ 3.55 \\ 3.86 \end{pmatrix}$$

x (cm)	y (cm)	Vg	J
7.05	0.15	-19.4	0.07
6.8	0.2	-18.8	0.10
6.35	0.45	-17.5	0.22
5.7	0.9	-15.7	0.44
5.3	1.2	-14.6	0.58
4.85	1.6	-13.4	0.78
4.5	1.95	-12.4	0.95
4.05	2.4	-11.2	1.17
3.65	2.9	-10.1	1.41
3	3.6	-8.3	1.75
2.4	4.3	-6.6	2.09
1.9	5.05	-5.2	2.45
1.4	5.75	-3.9	2.80
0.95	6.5	-2.6	3.16
0.6	7	-1.7	3.40
0.4	7.3	-1.1	3.55
0.05	7.95	-0.1	3.86

Fremlin fig.7 compared with Walker's formula

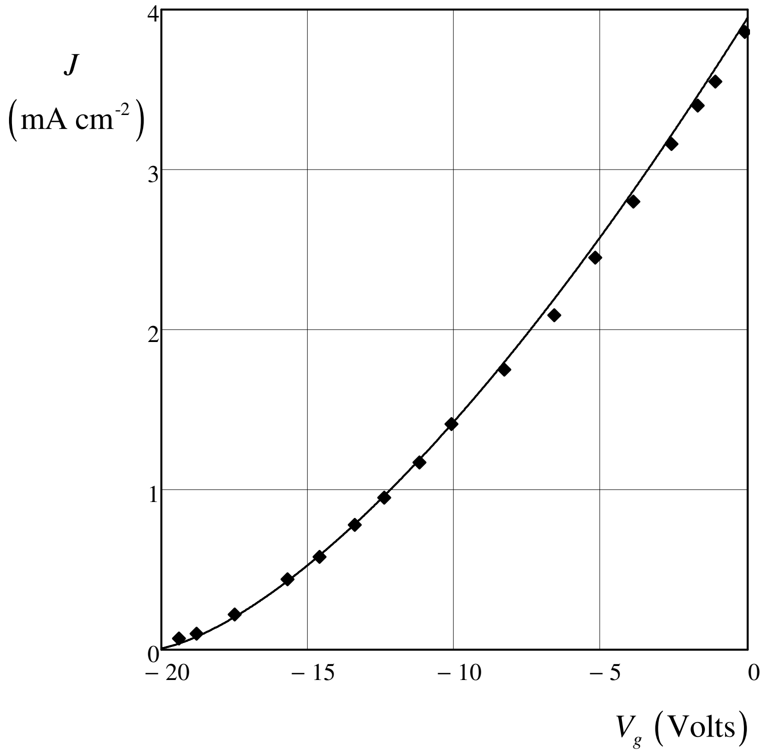


Figure 6.7