APPENDIX

About Graphs and Matrices in Mathcad

CHANGING NUMBERS IN A FILE AND PLOTTING A GRAPH

\[ x := 1, 2 \ldots 10 \quad a := 3 \quad b := 4 \quad f(x) := a \cdot x + b \]

\[ \lambda := 0.5 \quad A := 1 \quad T \equiv 1 \quad \delta 1 \equiv 1 \quad t 1 \equiv 0.1 \]

Specification of the number of \( x \) and \( t 1 \) values

\[ N := 15 \quad i := 0 \ldots N \quad j := 0 \ldots N \]

Specification of the range

\[ x_j := -0.4 + 0.025 \cdot i \quad t 1_j := -0.4 + 0.025 \cdot j \]
In the specification of the function only $x$ and $t_1$ are used

$$u_c(x, t_1) := \left[ 2 \cdot A \cdot \cos \left( 2 \cdot \pi \left( \frac{\delta_1}{2 \cdot \lambda} \right) \right) \cdot \left[ \cos \left( 2 \cdot \pi \cdot \left( \frac{x}{\lambda} - \frac{t_1}{T} \right) \right) - 2 \cdot \pi \left( \frac{\delta_1}{2 \cdot \lambda} \right) \right] \right]^2.$$  

In the plotting function one needs the $i$ and $j$ notation

$$M_{i,j} := u_c(x_i, t_{1j}).$$  

Call on “Surface plot” and type at the place holder just $M$ and push “F9.”

Go with the mouse on the graph and change the angle of the “point of view.” Click twice on the graph and get “3D-Plot Format” for “graph options.” Switch to contour plot.

**MATRICES**

Go to “Insert” and “Matrix” and select 2 by 2

$$\begin{pmatrix} & \cdot \\ \cdot & \cdot \end{pmatrix}$$

Type $M :=$  
Indicate the matrix and insert

$$M := \begin{pmatrix} & \cdot \\ \cdot & \cdot \end{pmatrix}$$

to get

$$M := \begin{pmatrix} & \cdot \\ \cdot & \cdot \end{pmatrix}$$
The manipulation of matrices can easily be seen from files containing matrices. Here we give an example of a matrix composed of functions and how to access the matrix elements after a multiplication has been done.

Fill in functions of \( x \) directly and call \( M \) now \( M(x) \quad x := 0, .1 \ldots 5 \)

\[
M(x) := \begin{pmatrix}
\cos(x) & -\sin(x) \\
+\sin(x) & \cos(x)
\end{pmatrix}
\]

One can access the matrix elements separately. Note that in Mathcad one starts with 0. For the 0, 1 and 1, 1 elements one has

\[
M(x)_{0,1} = M(x)_{1,1} =
\]

\[
\begin{array}{c|c}
0 & 1 \\
-0.1 & 0.995 \\
-0.199 & 0.98 \\
-0.296 & 0.955 \\
-0.389 & 0.921 \\
-0.479 & 0.878 \\
\end{array}
\]

Consider the matrix product \( M1(x) = M(x)^3 \). After multiplication one can again access the matrix elements

\[
M1(x) := M(x)^3 \quad \text{one gets for the 0, 1 element}
\]

\[
M1(x)_{0,1} =
\]

\[
\begin{array}{c}
0 \\
-0.296 \\
-0.565 \\
-0.783 \\
-0.932 \\
-0.997 \\
\end{array}
\]
**APPENDIX B**

**Formulas**

**CONSTANTS**

\[100\mu m \Rightarrow 3000 \text{ GHz}\]
\[100\mu m \Rightarrow 100 \text{ cm}^{-1}\]
\[10\mu m \Rightarrow 1000 \text{ cm}^{-1}\]
\[1 \text{ meV} = 10^3 \text{ eV} = 1.6 \times 10^{-16} \text{ joule} \Rightarrow 8.07 \text{ cm}^{-1}\]
\[100 \text{ nm} = 1000 \text{ Å}\]
\[10000 \text{ Å} = 1 \mu\]
\[1 \text{ Å} = 10^{-8} \text{ cm} = 10^{-10} \text{ m}\]

**FORMULAS**

\[
\sqrt{-1} = i \quad i^2 = -1
\]
\[z = a + ib = r(\cos \phi + i \sin \phi) = re^{i\phi}\]
\[
\cos x = \frac{e^{ix} + e^{-ix}}{2} \quad \sin x = \frac{e^{ix} - e^{-ix}}{2i}
\]
\[e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots, \quad \sin x = x - \frac{x^3}{3!} + \cdots, \quad \cos x = 1 - \frac{x^2}{2!} + \cdots\]
\[s_n = a + aq + aq^2 + \cdots + aq^{n-1} = a\frac{q^n - 1}{q - 1}\]
\[if |q| < 1, N \to \infty \quad s_\infty = \frac{a}{1-q}\]
\[ x^2 + ax + b = 0 \]
\[ x_{1,2} = \frac{-a \pm \sqrt{(a^2)} - b}{2} \]

\[ (1 \pm x)^n \approx 1 \pm nx \quad |x| < 1 \]

\[ \begin{pmatrix} a_1 & b_1 \\ a_2 & b_2 \end{pmatrix} \times \begin{pmatrix} c_1 & d_1 \\ c_2 & d_2 \end{pmatrix} = \begin{pmatrix} a_1c_1 + b_1c_2 & a_1d_1 + b_1d_2 \\ a_2c_1 + b_2c_2 & a_2d_1 + b_2d_2 \end{pmatrix} \]

\[ \begin{vmatrix} a_1b_1c_1 \\ a_2b_2c_2 \\ a_3b_3c_3 \end{vmatrix} = a_1 \begin{vmatrix} b_2c_2 \\ b_3c_3 \end{vmatrix} - a_2 \begin{vmatrix} b_1c_1 \\ b_3c_3 \end{vmatrix} + a_3 \begin{vmatrix} b_1c_1 \\ b_2c_2 \end{vmatrix} \]

\[ \begin{vmatrix} b_1c_1 \\ b_2c_2 \end{vmatrix} = b_1c_2 - b_2c_1 \]

**TRIGONOMETRIC FORMULAS**

\begin{center}
\begin{tabular}{r|cccccc}
\hline
& 0 & 30° & 45° & 60° & 90° & 180° & 270° & 360° \\
\hline
\sin & 0 & \frac{1}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{3}}{2} & 1 & 0 & -1 & 0 \\
\cos & 1 & \frac{\sqrt{3}}{2} & \frac{1}{2} & \frac{\sqrt{2}}{2} & \frac{1}{2} & 0 & 1 & 0 \\
\tan & 0 & \frac{\sqrt{3}}{3} & 1 & \sqrt{3} & \infty & 0 & \infty & 0 \\
\cot & \infty & \sqrt{3} & \frac{1}{3} & \frac{1}{\sqrt{3}} & 0 & \infty & 0 & \infty \\
\hline
\end{tabular}
\end{center}

\[ \sin^2 \alpha + \cos^2 \alpha = 1 \]
\[ \frac{\sin \alpha}{\cos \alpha} = \tan \alpha \quad \frac{\cos \alpha}{\sin \alpha} = \cot \alpha \]

\[ \tan \alpha = \frac{1}{\cos \alpha} \quad \cos^2 \alpha = 1 + \tan^2 \alpha \quad \sin \alpha = \frac{\tan \alpha}{\sqrt{1 + \tan^2 \alpha}} \quad \cos \alpha = \frac{1}{\sqrt{1 + \tan^2 \alpha}} \]

\[ \sin(90° \pm \alpha) = \cos \alpha \quad \sin(180° \pm \alpha) = \mp \sin \alpha \]
\[ \cos(90° \pm \alpha) = \mp \sin \alpha \quad \cos(180° \pm \alpha) = -\cos \alpha \]
\[ \tan(90° \pm \alpha) = \mp \cot \alpha \quad \tan(180° \pm \alpha) = \pm \tan \alpha \]
\[ \cot(90° \pm \alpha) = \mp \tan \alpha \quad \cot(180° \pm \alpha) = \pm \cot \alpha \]

\[ \sin(-\alpha) = -\sin \alpha \quad \sin(\alpha \pm \beta) = \sin \alpha \cos \beta \pm \cos \alpha \sin \beta \]
\[ \cos(-\alpha) = +\cos \alpha \quad \cos(\alpha \pm \beta) = \cos \alpha \cos \beta \mp \sin \alpha \sin \beta \]
\[ \tan(-\alpha) = -\tan \alpha \quad \tan(\pm \alpha \pm \beta) = \frac{\tan \alpha \pm \tan \beta}{1 \mp \tan \alpha \cdot \tan \beta} \]
\[ \cot(-\alpha) = -\cot \alpha \quad \cot(\alpha \pm \beta) = \frac{\cot \alpha \cdot \beta \pm 1}{\cot \beta \pm \cot \alpha} \]
\[
\sin 2\alpha = 2 \sin \alpha \cos \alpha \\
\cos 2\alpha = \cos^2 \alpha - \sin^2 \alpha = 1 - 2 \sin^2 \alpha = 2 \cos^2 \alpha - 1 \\
\sin 2\alpha = \frac{2 \tan \alpha}{1 + \tan^2 \alpha} \quad \cos 2\alpha = \frac{1 - \tan^2 \alpha}{1 + \tan^2 \alpha} \\
\tan^2 \alpha = \frac{2 \tan \alpha}{1 - \tan^2 \alpha} = \frac{2}{\cot \alpha - \tan \alpha}, \quad \cot 2\alpha = \frac{\cot^2 \alpha - 1}{2 \cot \alpha} = \frac{1}{2} (\cot \alpha - \tan \alpha) \\
1 + \cos \alpha = 2 \cos^2 \frac{\alpha}{2}, \quad 1 - \cos \alpha = 2 \sin^2 \frac{\alpha}{2} \\
\tan \alpha = \sqrt{\frac{1 - \cos 2\alpha}{1 + \cos 2\alpha}} = \frac{\sin 2\alpha}{1 + \cos 2\alpha} = \frac{1 - \cos 2\alpha}{1 - \tan^2 \frac{\alpha}{2}} = \frac{2 \tan \frac{\alpha}{2}}{1 - \tan^2 \frac{\alpha}{2}} \\
\sin \alpha + \sin \beta = 2 \sin \frac{\alpha + \beta}{2} \cdot \cos \frac{\alpha - \beta}{2} \quad \frac{\sin \alpha + \sin \beta}{\cos \alpha + \cos \beta} = \tan \frac{\alpha + \beta}{2} \\
\sin \alpha - \sin \beta = 2 \cos \frac{\alpha + \beta}{2} \cdot \sin \frac{\alpha - \beta}{2} \\
\cos \alpha + \cos \beta = 2 \cos \frac{\alpha + \beta}{2} \cdot \cos \frac{\alpha - \beta}{2} \quad \frac{\sin \alpha - \sin \beta}{\cos \alpha + \cos \beta} = \tan \frac{\alpha - \beta}{2} \\
\cos \alpha - \cos \beta = -2 \sin \frac{\alpha + \beta}{2} \cdot \sin \frac{\alpha - \beta}{2} \\
\frac{\tan \alpha + \tan \beta}{\cot \alpha + \cot \beta} = \tan \alpha \cdot \tan \beta \\
\tan \alpha + \tan \beta = \frac{\sin(\alpha \pm \beta)}{\cos \alpha \cos \beta} \quad \frac{1 + \tan \alpha}{1 - \tan \alpha} = \tan(45^\circ + \alpha) \\
\cot \alpha \pm \cot \beta = \frac{\pm \sin(\alpha \pm \beta)}{\sin \alpha \sin \beta} \quad \cot \alpha + 1 = \cot(45^\circ - \alpha) \\
\cot \alpha - \tan \alpha = \frac{2}{\sin 2\alpha} \quad \cot \alpha - \tan \alpha = 2 \cot 2\alpha
\]
DIFFERENTIATION

\[(u \cdot v)' = uv' + u'v\]
\[\left(\frac{u}{v}\right)' = \frac{u'v - v'u}{v^2}\]
\[(\sin x)' = \cos x \quad (e^x)' = e^x\]
\[(\cos x)' = -\sin x \quad (\ln x)' = \frac{1}{x}\]
\[(\tan x)' = \frac{1}{\cos^2 x} \quad (\arcsin x)' = \frac{1}{\sqrt{1 - x^2}}\]
\[(\cot x)' = -\frac{1}{\sin^2 x} \quad (\arccos x)' = -\frac{1}{\sqrt{1 - x^2}}\]

INTEGRATION

\[\int u dv = uv - \int v du\]
\[\int dx = x \quad \int x^n dx = \frac{x^{n+1}}{n+1} \quad \int \frac{dx}{x} = \ln x\]
\[\int \sin x dx = -\cos x \quad \int \cos x dx = \sin x\]
\[\int \cot x dx = \ln \sin x \quad \int \frac{dx}{\sin^2 x} = -\cot x\]
\[\int \frac{dx}{\cos^2 x} = \tan x\]
\[\int \frac{dx}{1-x^2} = \ln \frac{1+x}{1-x}\]
\[\int \frac{dx}{\sqrt{1-x^2}} = \arcsin x \quad \int \frac{dx}{1+x^2} = +\arctan x\]
\[\int e^x dx = e^x \quad \int a^x dx = \frac{a^x}{\ln a} \quad \int \frac{dx}{x \pm a} = \ln(x \pm a)\]
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