

**Calculate &  
Communicate  
with PTC  
Mathcad Prime 3.0**

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# Calculate & Communicate

*with PTC Mathcad Prime 3.0*

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# Instructions

This book accompanies the do-it-yourself course *Calculate & Communicate with PTC Mathcad Prime 3.0*. In this course you will learn to use large parts of applied mathematics on a computer. You will also learn to write up your calculations in such a way that others will be able to follow and use what you are doing.

## *Course Instructions*

The course consists of 25 interactive lessons, each accompanied by at least one computer exercise. You must download these from the PTC website. The lesson files are read-only, so you can practice without really changing them. (You can save your own files under a different name.) Each lesson, with exercises, should take between a half and a whole hour. The lesson will give you an idea of what can be done - you will need more time to practice using it on real problems. Files with answers to the exercises are available, but we advise you not to look at these before you have tried the exercises yourself.

There are five parts. The first two, comprising 12 lessons, should be useful for everybody using Mathcad Prime 3.0 or its free sibling Mathcad Express 3.0. The last three parts (13 lessons) are meant for those who already know calculus. Most of these lessons required the full Prime 3.0.

**To begin, open the lesson '1 Introducing Mathcad' in PTC Mathcad Prime 3.0 and work through it.** The lessons closely follow those in this book, but you will be using the live program on screen.

## *What is New?*

If you are working with earlier versions 15 or earlier of Mathcad, you are in for some re-learning. Mathcad Prime is not 'just an upgrade'. The whole program has been revamped - the interface, but also the content and way of working. Your cunning workarounds for program inconsistencies may no longer work (what a disappointment); but then you may no longer need them (what a relief!). You will have to get used to new ways of editing - but will find that these are easier to understand and remember. It takes a little time to find your way in the interface with ribbons, but once you have done that, you will never want to go back. We suggest that you at least try lesson 1 (the interface), 6 (editing of equations), 7 (2D plots), 9 (3D plots), 10 (labels and units), 17 (Excel) and 21 (vectors and matrices). The changes are the largest in these subjects.

For users of Mathcad Prime 1.0 or 2.0 the changes are less important. The big ones are in lesson 6 (editing of equations), but you will find many smaller changes in lesson 1 (the interface), lesson 3 (templates) and lesson 7 (labels and global variables). We have partly rewritten lessons 11 and 12 on programming, and lessons 13 through 16 on statistics.

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Part 1

## Basics

Introducing Mathcad

Handling of Text

Worksheet Layout

Mathcad as Calculator

Variables and Functions

Editing of Equations

# 1 Introducing Mathcad

In this course, you will learn to use mathematics with PTC Mathcad Prime 3.0. Why Mathcad? There are several reasons:

1. It handles all mathematical tasks under a single interface.
2. These are in standard symbolic or numerical notation.
3. Calculations can be embedded in text, with plots and illustrations.
4. The calculations are live, as in a spreadsheet. So they are easily modified and corrected.
5. The results are readable by any scientist or engineer (not only Mathcad users). So they can be used to *communicate* with others.

Mathcad is very useful for problems where you need to be flexible and creative: when you are learning a subject, doing homework, designing, or developing a new product or theory... You can even write a book in it, as this text shows.

If you do not know Mathcad, you will need to spend some time learning the program. The interface is intuitive, but there are lots of details to be mastered. This set of Mathcad files should help you. It consists of lessons on the following subjects:

Basics	1 Introducing Mathcad (this lesson)
	2 Handling of Text
	3 Worksheet Layout
	4 Mathcad as Calculator
	5 Variables and Functions
	6 Editing of Equations
Further	7 Ranges and Plots
	8 2D Plots of Functions
	9 3D Plots of Functions
	10 Labels and Units
	11 Programming - Branches
	12 Programming - Loops
Applied	13 Statistics
	14 Distributions
	15 Testing
	16 Data Analysis
	17 Input / Output
Symbolic	18 Symbolic Calculus
	19 Solve and Series
	20 Shaping Equations
	21 Vectors and Matrices

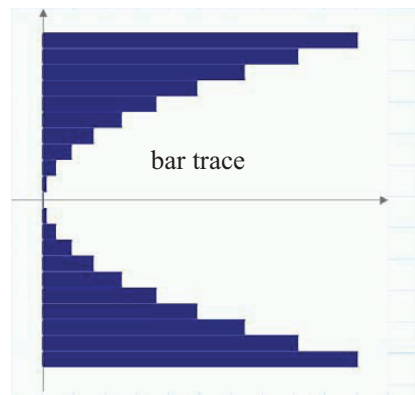
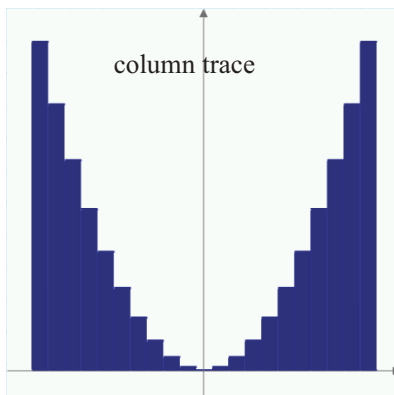
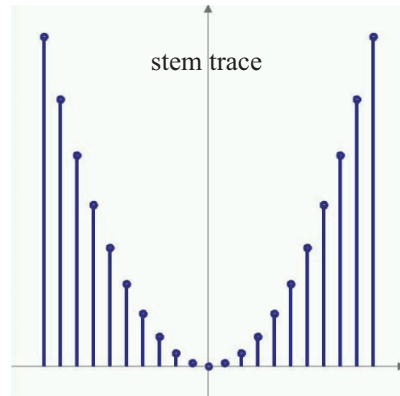
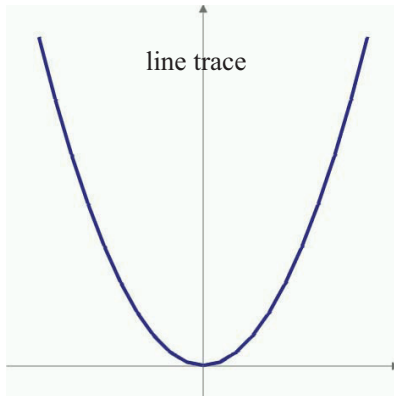
*continued on the next page*

## 8 2D Plots of Functions

In this lesson we explore the many variations in plots. We use the same terms as in lesson 7. Check that you have the names of the plot elements in your mind.

### Trace Types

To change the type of a trace, activate its  $y$ -legend, then choose from Plots > Traces > Change Type. Below are images using the first four types.



There are more trace types in the list: we will use some of them further on. If you are reading this file on screen, switch to Draft view and try the different types in the plot on the right. (With the bar trace you need to exchange the axes to get the figure above.) While you are doing this, also look at the effect of changing both type and trace thickness.

### Multiple Traces

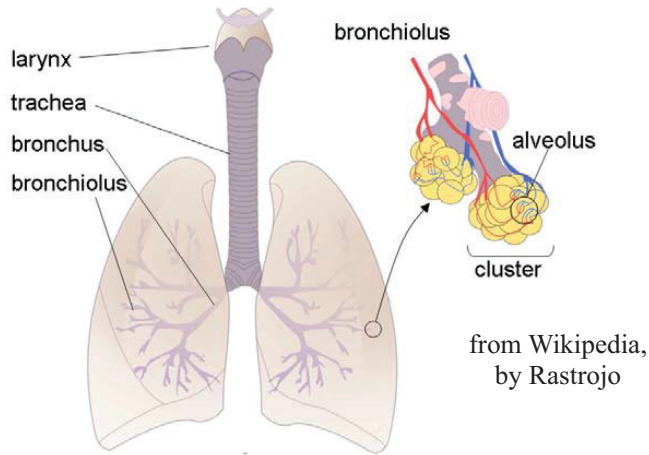
To add a trace to a plot, select the  $y$ -legend in the plot and apply Plots > Traces > Add Trace. A new  $y$ -legend will appear. You can add more legends. You can also add  $x$ -legends, but we will not do so here.



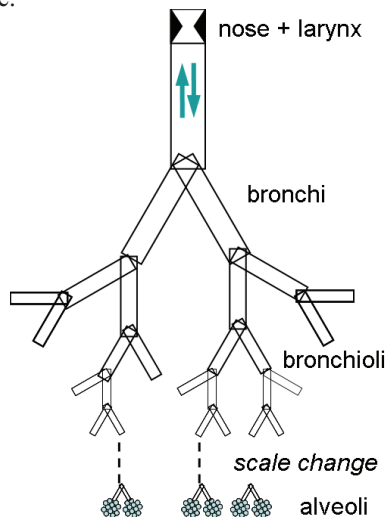
## 18-7 Fractal Lung

30 min

This file considers a model of the lungs, of which you see an image below.



You see a large air tube (the trachea) splitting into finer and finer tubes (the bronchi and bronchioli) and ending in clusters of alveoli. The alveoli provide the huge area required for exchange of oxygen and carbon dioxide between the body and the atmosphere. We will model the tubes using a 'fractal' structure.



### *Fractal Structure*

In this structure the initial tube splits in two, the following also splits and so down to smaller and smaller levels. The word 'fractal' implies that the shape remains the same at each level - here that the length over diameter ratio is the same for all tubes. Nature often seems to emulate fractal structures - and they can have simple mathematical properties.

# 21 Vectors and Matrices

You may know a lot about this subject without having realised. A column in an Excel spreadsheet is a column *vector*. A row of figures is a *row vector*. A block of figures is a *matrix*. These are *arrays* of numbers. Calculations in Excel are vector and matrix operations... You can do these in Mathcad with the advantage that calculations are much easier to follow.

## Introduction

ORIGIN = 1

So far our vectors have always started with element '0'. In this lesson it is simpler to let them start at '1'. You do this with Calculation > Worksheet Settings > Origin. We always put this change in the heading of a worksheet - it can be confusing if you forget. Now look at a few matrices:

$$\mathbf{M} := \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \quad \mathbf{S} := \begin{bmatrix} a & b \\ c & d \end{bmatrix} \quad \mathbf{R}(\theta) := \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix}$$

As you see, they may contain numbers ('scalars'), symbols or even functions. They may also contain elements of text ('strings'), but we will not use these. We have given all matrix names the system label: this gives the bold upright letters used in math texts. The elements of a matrix can be output using subscripts:

$$\mathbf{M}_{2,2} \rightarrow 4 \quad \mathbf{S}_{1,2} \rightarrow b \quad \mathbf{R}\left(\frac{\pi}{6}\right)_{1,1} \rightarrow \frac{\sqrt{3}}{2}$$

The matrices above are 2x2 squares, but arrays can have any dimensions as long as they are rectangular:

$$[-3] \quad 1 \times 1 \text{ array: an ordinary number} \quad \mathbf{v} := [4 \ 5 \ 6] \quad 1 \times 3 \text{ array: a row vector}$$

$$\mathbf{u} := \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix} \quad 3 \times 1 \text{ array: a column vector}$$

$$\mathbf{W} := \begin{bmatrix} 1 & -7 & 13 \\ 3 & 2 & 6 \\ -4 & 11 & 0 \end{bmatrix} \quad 3 \times 3 \text{ matrix} \quad \begin{bmatrix} p & q \\ r & s \\ t & u \\ v & w \end{bmatrix} \quad 4 \times 2 \text{ matrix}$$

**remember:**  
rows first, columns second

Also here the elements are extracted using subscripts:  $\mathbf{u}_{2,1} = 2$      $\mathbf{v}_{1,3} = 6$      $\mathbf{W}_{3,2} = 11$

For column vectors you can omit the second subscript, but not for row vectors.  $\mathbf{u}_2 = 2$      $\mathbf{v}_2 = ?$

Under Math > Operators and Symbols > Operators > Vector and Matrix you will find commands for extracting columns and rows:

$$\mathbf{W}^{(1)} = \begin{bmatrix} 1 \\ 3 \\ -4 \end{bmatrix} \quad \widehat{\mathbf{W}}_1 = [1 \ -7 \ 13]$$