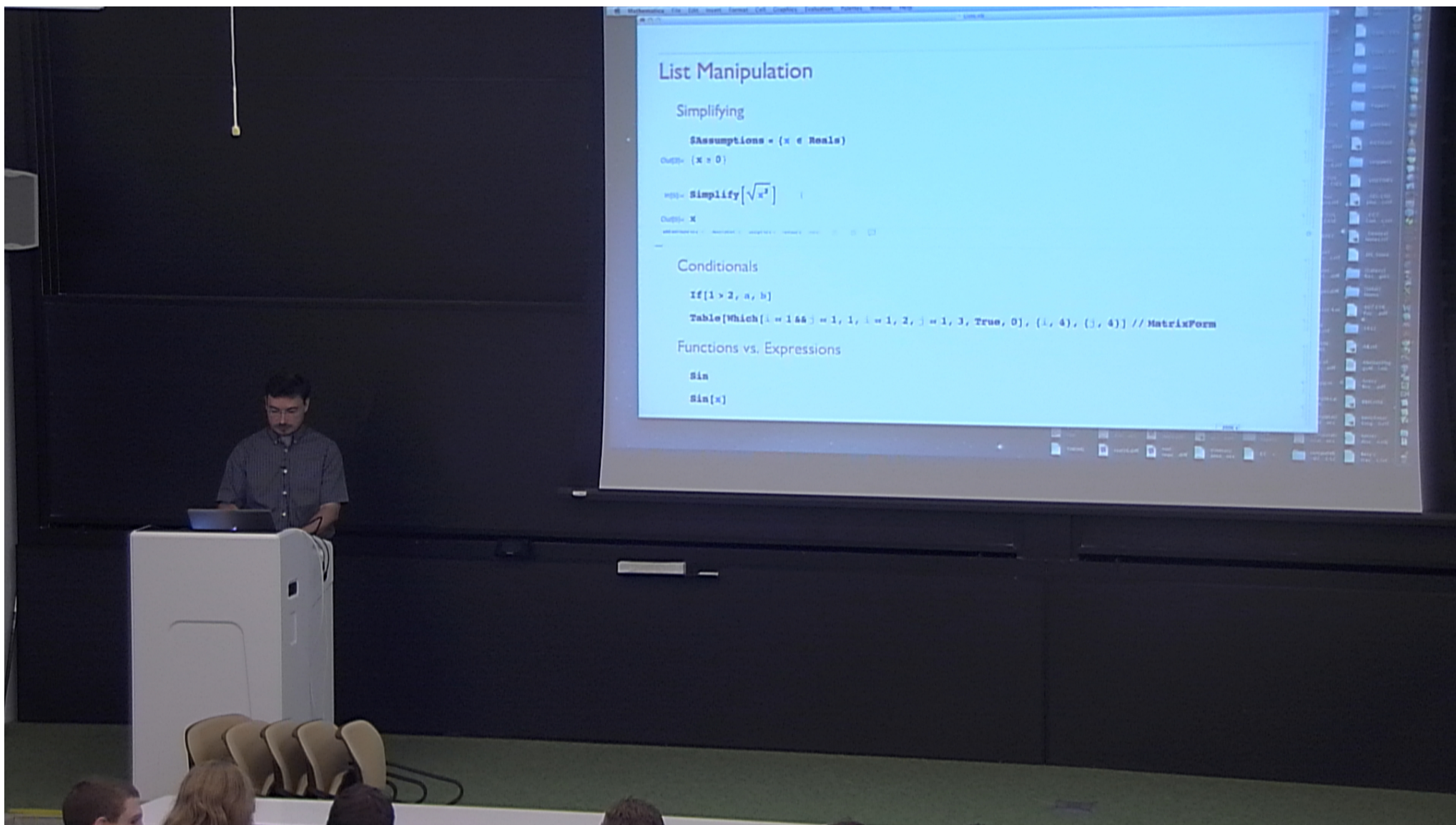


Title: 13/14 PSI - Computational Methods in Physics - Lecture 2

Date: Sep 04, 2013 09:00 AM

URL: <http://pirsa.org/13090053>

Abstract:



List Manipulation

Simplifying

```
$Assumptions = {x ∈ Reals}
```

```
Out[20]= {x ∈ 0}
```

```
in[20]= Simplify[ $\sqrt{x^2}$ ]
```

```
Out[20]= x
```

Conditionals

```
If[1 > 2, a, b]
```

```
Table[Which[i == 1 && j == 1, 1, i == 1, 2, j == 1, 3, True, 0], {i, 4}, {j, 4}] // MatrixForm
```

Functions vs. Expressions

```
Sin
```

```
Sin[x]
```


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Lists.nb

List Manipulation

Simplifying

```
$Assumptions = {x ∈ Reals}
```

```
Out[3]= {x ≥ 0}
```

```
In[5]:= Simplify[√x²]
```

```
Out[5]= x
```

Conditionals

```
In[6]:= If[1 > 2, a, b]
```

```
Out[6]= b
```

```
In[7]:= Table[Which[i == 1 && j == 1, 1, i == 1, 2, j == 1, 3, True, 0], {i, 4}, {j, 4}] // MatrixForm
```

```
Out[7]//MatrixForm=
```

$$\begin{pmatrix} 1 & 2 & 2 & 2 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \end{pmatrix}$$

Assuming a matrix | Use as a list of lists instead

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Lists.nb

List Manipulation

Simplifying

In[12]:= `$Assumptions = {x ∈ Reals}`

Out[12]= `{x ∈ Reals}`

In[13]:= `Simplify[ $\sqrt{x^2}$ ]`

Out[13]= `Abs[x]`

plot convert to Conjugate x derivative x integral more...

Conditionals

In[6]:= `If[1 > 2, a, b]`

Out[6]= `b`

In[7]:= `Table[Which[i == 1 && j == 1, 1, i == 1, 2, j == 1, 3, True, 0], {i, 4}, {j, 4}] // MatrixForm`

Out[7]//MatrixForm=

$$\begin{pmatrix} 1 & 2 & 2 & 2 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \end{pmatrix}$$

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Lists.nb

```
In[12]:= $Assumptions = {x ∈ Reals}
Out[12]=
{ x ∈ Reals }
```

```
In[13]:= Simplify[ $\sqrt{x^2}$ ]
Out[13]=
Abs[x]
```

Conditionals

```
In[6]:= If[1 > 2, a, b]
Out[6]= b
```

```
In[7]:= Table[Which[i == 1 && j == 1, 1, i == 1, 2, j == 1, 3, True, 0], {i, 4}, {j, 4}] // MatrixForm
Out[7]//MatrixForm=

$$\begin{pmatrix} 1 & 2 & 2 & 2 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \end{pmatrix}$$

```

Functions vs. Expressions

```
In[14]:= Sin
Out[14]=
Sin
```

documentation usps macos attributes description more

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Lists.nb

```
In[7]:= Table[Which[i == 1 && j == 1, 1, i == 1, 2, j == 1, 3, True, 0], {i, 4}, {j, 4}] // MatrixForm
```

Out[7]//MatrixForm=

$$\begin{pmatrix} 1 & 2 & 2 & 2 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \end{pmatrix}$$

Functions vs. Expressions

```
In[14]:= Sin
```

Out[14]=

Sin

```
In[15]:= Sin[x]
```

Out[15]=

Sin[x]

```
In[16]:= Sin[#] &
```

Out[16]=

Sin[#1] &

```
In[17]:= Sin[#] & [x]
```

Out[17]=

Sin[x]

plot x derivative x integral convert to exponential form more...

Function[{x}, Sin[x]]

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Lists.nb

$$\begin{pmatrix} 3 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 \end{pmatrix}$$

Functions vs. Expressions

In[14]:= **Sin**

Out[14]= Sin

In[15]:= **Sin[x]**

Out[15]= Sin[x]

In[16]:= **Sin[#] &**

Out[16]= Sin[#1] &

In[17]:= **Sin[#] &[x]**

Out[17]= Sin[x]

In[18]:= **Function[{x}, Sin[x]]**

Out[18]= Function[{x}, Sin[x]]

D[Sin, x]

D[Sin[x], x]

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Lists.nb

Out[14]= Sin

In[15]:= Sin[x]

Out[15]= Sin[x]

In[16]:= Sin[#] &

Out[16]= Sin[#1] &

In[17]:= Sin[#] &[x]

Out[17]= Sin[x]

In[18]:= Function[{x}, Sin[x]]

Out[18]= Function[{x}, Sin[x]]

In[19]:= D[Sin, x]

Out[19]= 0

In[20]:= D[Sin[x], x]

Out[20]= Cos[x]

plot x derivative x integral convert to exponential form more...

Derivative[1][Sin]

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Lists.nb

```

Out[15]=
Sin[x]

In[16]:= Sin[#] &
Out[16]=
Sin[#1] &

In[17]:= Sin[#] & [x]
Out[17]=
Sin[x]

In[18]:= Function[{x}, Sin[x]]
Out[18]=
Function[{x}, Sin[x]]

In[19]:= D[Sin, x]
Out[19]=
0

In[20]:= D[Sin[x], x]
Out[20]=
Cos[x]

In[21]:= Derivative[1][Sin]
Out[21]=
Cos[#1] &

plot evaluate at point... differentiate integrate

```

Derivative[1][Sin[x]]

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Lists.nb

Out[16]=

$$\text{Sin}[\#1] \&$$

In[17]:= **Sin**[#] &[x]

Out[17]=

$$\text{Sin}[x]$$

In[18]:= **Function**[{x}, **Sin**[x]]

Out[18]=

$$\text{Function}[\{x\}, \text{Sin}[x]]$$

In[19]:= **D**[**Sin**, x]

Out[19]=

$$0$$

In[20]:= **D**[**Sin**[x], x]

Out[20]=

$$\text{Cos}[x]$$

In[21]:= **Derivative**[1][**Sin**]

Out[21]=

$$\text{Cos}[\#1] \&$$

In[22]:= **Derivative**[1][**Sin**[x]]

Out[22]=

$$\text{Sin}[x]'$$

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Lists.nb

```

Out[17]=
Sin[x]

In[18]:= Function[{x}, Sin[x]]
Out[18]=
Function[{x}, Sin[x]]

In[19]:= D[Sin, x]
Out[19]=
0

In[20]:= D[Sin[x], x]
Out[20]=
Cos[x]

In[21]:= Derivative[1][Sin]
Out[21]=
Cos[#1] &

Derivative[1][Sin[x]]

Out[23]=
Sin[1]'

x

Lists

list = Range[10]

```

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Lists.nb

```

Out[17]= Sin[x]

In[18]:= Function[{x}, Sin[x]]
Out[18]= Function[{x}, Sin[x]]

In[19]:= D[Sin, x]
Out[19]= 0

In[20]:= D[Sin[x], x]
Out[20]= Cos[x]

In[21]:= Derivative[1][Sin]
Out[21]= Cos[#1] &

In[25]:= Derivative[1][Sin[#] &]
Out[25]= Cos[#1] &

```

plot evaluate at point... differentiate integrate

Lists

```
list = Range[10]
```

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Lists.nb

```
Out[17]= Sin[x]

In[18]:= Function[{x}, Sin[x]]
Out[18]= Function[{x}, Sin[x]]

In[19]:= D[Sin, x]
Out[19]= 0

In[20]:= D[Sin[x], x]
Out[20]= Cos[x]

In[21]:= Derivative[1][Sin]
Out[21]= Cos[#1] &

In[26]:= Derivative[1][Sin[x]]
Out[26]= Sin[x]'
```

Lists

```
list = Range[10]

First[list]
```

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Lists.nb

```
In[21]:= Derivative[1][Sin]
Out[21]= Cos[#1] &

In[26]:= Derivative[1][Sin[x]]
Out[26]= Sin[x]'
```

Lists

```
In[27]:= list = Range[10]
Out[27]= {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}

In[28]:= First[list]
Out[28]= 1

In[29]:= Last[list]
Out[29]= 10

Take[list, 3]

Drop[list, 5]

Append[list, x]

Join[list, {x, v, z}]
```

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Lists.nb

```
Out[28]=  
1  
  
In[29]:= Last[list]  
Out[29]=  
10  
  
In[30]:= Take[list, 3]  
Out[30]=  
{1, 2, 3}  
  
In[31]:= Drop[list, 5]  
Out[31]=  
{6, 7, 8, 9, 10}  
  
In[32]:= Append[list, x]  
Out[32]=  
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x}  
  
In[33]:= Join[list, {x, y, z}]  
Out[33]=  
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}  
  
Flatten[{{1, 2}, {3, 4}}]  
Partition[list, 3]
```

Selecting and Patterns

200%

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Lists.nb

```
Out[28]=  
1  
  
In[29]:= Last[list]  
Out[29]=  
10  
  
In[30]:= Take[list, 3]  
Out[30]=  
{1, 2, 3}  
  
In[31]:= Drop[list, 5]  
Out[31]=  
{6, 7, 8, 9, 10}  
  
In[32]:= Append[list, x]  
Out[32]=  
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x}  
  
In[33]:= Join[list, {x, y, z}]  
Out[33]=  
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}  
  
Flatten[{{1, 2}, {3, 4}}]  
Partition[list, 3]
```

Selecting and Patterns

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Lists.nb

10

In[30]:= **Take**[list, 3]

Out[30]=

{1, 2, 3}

In[31]:= **Drop**[list, 5]

Out[31]=

{6, 7, 8, 9, 10}

In[32]:= **Append**[list, x]

Out[32]=

{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x}

In[33]:= **Join**[list, {x, y, z}]

Out[33]=

{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}

In[34]:= **Flatten**[{{1, 2}, {3, 4}}]

Out[34]=

{1, 2, 3, 4}

Partition[list, 3]

Selecting and Patterns

Select[list, # ≥ 5 &]

Select[list, Mod[#, 2] == 0 &]

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Lists.nb

10

In[30]:= **Take**[list, 3]

Out[30]=

{1, 2, 3}

In[31]:= **Drop**[list, 5]

Out[31]=

{6, 7, 8, 9, 10}

In[32]:= **Append**[list, x]

Out[32]=

{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x}

In[33]:= **Join**[list, {x, y, z}]

Out[33]=

{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}

In[34]:= **Flatten**[{{1, 2}, {3, 4}}]

Out[34]=

{1, 2, 3, 4}

In[35]:= **Partition**[list, 3]

Out[35]=

{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}}

Assuming a matrix | Use as a list of lists instead

matrix plot determinant matrix rank eigenvalues more...

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10

```
In[30]:= Take[list, 3]
Out[30]= {1, 2, 3}

In[31]:= Drop[list, 5]
Out[31]= {6, 7, 8, 9, 10}

In[32]:= Append[list, x]
Out[32]= {1, 2, 3, 4, 5, 6, 7, 8, 9, x}

In[33]:= Join[list, {x, y, z}]
Out[33]= {1, 2, 3, 4, 5, 6, 7, 8, 9, x, y, z}

In[34]:= Flatten[{{1, 2}, {3, 4}}]
Out[34]= {1, 2, 3, 4}

In[35]:= Partition[list, 3]
Out[35]= {{1, 2, 3}, {4, 5, 6}, {7, 8, 9}, {10}}
```

Assuming a matrix | Use as a list of lists instead
matrix plot | determinant | matrix rank | eigenvalues | more...

Search Results: list

1 - 10 of 5200 for list

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- List** (Built-in Mathematica Symbol)
{e₁, e₂, ...} is a list of elements.
- List** (Mathematica Import/Export Format)
Column of numbers or strings. Stores a list of numbers or strings as lines. Plain text format. Is essentially a single-column version of the "Table" format.
- List Manipulation** (Mathematica Guide)
Lists are central constructs in Mathematica, used to represent collections, arrays, sets, and sequences of all kinds. Lists can have any structure and size, and can routinely ...
- New in 6.0: List Manipulation** (Mathematica Guide)
Widely recognized as the world's most powerful list manipulation language, Mathematica added in Version 6.0 a number of important new functions. Each function was carefully ...
- Adding, Removing, and Modifying List Elements** (Mathematica Tutorial)
Functions for manipulating elements in explicit lists. This gives a list with x prepended. This inserts x so that it becomes element number 2.
- Lists** (Mathematica Overview)
Making Lists of Objects Collecting Objects Together Making Tables of Values
- Constructing Lists** (Mathematica Tutorial)
Lists are widely used in Mathematica, and there are many ways to construct them. Some explicit ways to construct lists. This gives a table of the first five powers of 2.
- Manipulating Elements of Lists** (Mathematica Tutorial)
Many of the most powerful list manipulation operations in Mathematica treat whole lists as single objects. Sometimes, however, you need to pick out or set individual elements ...
- Lists as Sets** (Mathematica Tutorial)
Mathematica usually keeps the elements of a list in exactly the order you originally entered them. If you want to treat a Mathematica list like a mathematical set, however, ...
- Testing and Searching List Elements** (Mathematica Tutorial)
Testing and searching for elements of lists. "Getting Pieces of Lists" discusses how to extract pieces of lists based on their positions or indices. Mathematica also has ...

100%

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Lists.nb

```
10

In[30]:= Take[list, 3]
Out[30]=
{1, 2, 3}

In[31]:= Drop[list, 5]
Out[31]=
{6, 7, 8, 9, 10}

In[32]:= Append[list, x]
Out[32]=
{1, 2, 3, 4, 5, 6, 7, 8, 9, x}

In[33]:= Join[list, {x, y, z}]
Out[33]=
{1, 2, 3, 4, 5, 6, 7, 8, 9, x, y, z}

In[34]:= Flatten[{1, 2}, {3, 4}]
Out[34]=
{1, 2, 3, 4}

In[35]:= Partition[list, 3]
Out[35]=
{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}, {10}}
```

Assuming a matrix | Use as a list of lists instead
matrix plot | determinant | matrix rank | eigenvalues | more...

List Manipulation – Wolfram Mathematica

Mathematica > Core Language > List Manipulation

guide/ListManipulation

List Manipulation

Lists are central constructs in *Mathematica*, used to represent collections, arrays, sets, and sequences of all kinds. Lists can have any structure and size, and can routinely involve even millions of elements. Well over a thousand built-in functions throughout *Mathematica* operate directly on lists, making lists a powerful vehicle for interoperability.

Learning Resources

Featured Examples

- Analyze Words in a Block of Text
- Arbitrarily Nested Tables
- Arrange Controls Using Typesetting Constructs
- Automatically Parallelize Computations

Reference

Constructing Lists

- List** — specify a list explicitly
- Table** — make a table of values of an expression
- Array** — make an array of any dimension from a function
- Range** · **SparseArray** · **Tuples** · **NestList** · **Sow** · **Reap** · ...

Elements of Lists

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10

```
In[30]:= Take[list, 3]
Out[30]= {1, 2, 3}

In[31]:= Drop[list, 5]
Out[31]= {6, 7, 8, 9, 10}

In[32]:= Append[list, x]
Out[32]= {1, 2, 3, 4, 5, 6, 7, 8, 9, x}

In[33]:= Join[list, {x, y, z}]
Out[33]= {1, 2, 3, 4, 5, 6, 7, 8, 9, x, y, z}

In[34]:= Flatten[{1, 2}, {3, 4}]
Out[34]= {1, 2, 3, 4}

In[35]:= Partition[list, 3]
Out[35]= {{1, 2, 3}, {4, 5, 6}, {7, 8, 9}, {10}}
```

Assuming a matrix | Use as a list of lists instead
matrix plot | determinant | matrix rank | eigenvalues | more...

List Manipulation - Wolfram Mathematica

Mathematica > Core Language > List Manipulation

guide/ListManipulation

Reference

Constructing Lists >

- List** (`{a,b,...}`) — specify a list explicitly
- Table** — make a table of values of an expression
- Array** — make an array of any dimension from a function
- Range** · **SparseArray** · **Tuples** · **NestList** · **Sow** · **Reap** · ...

Elements of Lists >

- Part** (`list[[...]]`) — parts or sequences of parts (`{i,j}`), resettable with `Part`
- First** · **Last** · **Take** · **Drop** · **Extract** · **Append** · **ReplacePart** · ...
- Select** — select according to a function
- Cases** — give cases matching a pattern
- Length** · **Position** · **MemberQ** · **DeleteDuplicates** · ...

Rearranging & Restructuring Lists >

- Flatten** — flatten out nested lists
- Join** · **Partition** · **Transpose** · **Reverse** · **Sort** · **Split** · **Gather** · **Riffle** · ...

Applying Functions to Lists >

- Map** (`f /@ list`) — map a function over a list: $f \rightarrow \{f[a], f[b], f[c]\}$
- Apply** (`f @@ list`) — apply a function to a list: $f \rightarrow f[a, b, c]$
- MapIndexed** · **Scan** · **Thread** · **MapThread** · **Outer** · **FoldList** · ...

Math & Counting Operations >

- Total** · **Differences** · **Tally** · **Count** · **BinCounts** · ...

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Lists.nb

```
{1, 2, 3}
```

In[31]:= **Drop**[list, 5]

Out[31]=

```
{6, 7, 8, 9, 10}
```

In[32]:= **Append**[list, x]

Out[32]=

```
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x}
```

In[33]:= **Join**[list, {x, y, z}]

Out[33]=

```
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}
```

In[34]:= **Flatten**[{{1, 2}, {3, 4}}]

Out[34]=

```
{1, 2, 3, 4}
```

In[35]:= **Partition**[list, 3]

Out[35]=

```
{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}}
```

Selecting and Patterns

Select[list, # ≥ 5 &]

Select[list, Mod[#, 2] == 0 &]

list2 = {1. 2. 3. x. v. z. x^2. x^3}

200%

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Lists.nb

```
In[32]:= Append[list, x]
Out[32]=
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x}

In[33]:= Join[list, {x, y, z}]
Out[33]=
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}

In[34]:= Flatten[{{1, 2}, {3, 4}}]
Out[34]=
{1, 2, 3, 4}

In[35]:= Partition[list, 3]
Out[35]=
{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}}
```

Selecting and Patterns

```
In[36]:= Select[list, # >= 5 &]
Out[36]=
{5, 6, 7, 8, 9, 10}

Select[list, Mod[#, 2] == 0 &]
list2 = {1, 2, 3, x, y, z, x^2, x^3}
Cases[list2, _Integer]
Cases[list2, ^2]
```

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Lists.nb

```
In[33]:= Join[list, {x, y, z}]
Out[33]= {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, x, y, z}
```

```
In[34]:= Flatten[{{1, 2}, {3, 4}}]
Out[34]= {1, 2, 3, 4}
```

```
In[35]:= Partition[list, 3]
Out[35]= {{1, 2, 3}, {4, 5, 6}, {7, 8, 9}}
```

Selecting and Patterns

```
In[36]:= Select[list, # >= 5 &]
Out[36]= {5, 6, 7, 8, 9, 10}
```

```
In[37]:= Select[list, Mod[#, 2] == 0 &]
Out[37]= {2, 4, 6, 8, 10}
```

```
In[38]:= list2 = {1, 2, 3, x, y, z, x^2, x^3}
Out[38]= {1, 2, 3, x, y, z, x^2, x^3}
```

Groebner basis curl div polynomial reduce more...

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Lists.nb

```
In[34]:= Flatten[{1, 2}, {3, 4}]
```

Out[34]=

$$\{1, 2, 3, 4\}$$

```
In[35]:= Partition[list, 3]
```

Out[35]=

$$\{\{1, 2, 3\}, \{4, 5, 6\}, \{7, 8, 9\}\}$$

Selecting and Patterns

```
In[36]:= Select[list, # > 5 &]
```

Out[36]=

$$\{5, 6, 7, 8, 9, 10\}$$

```
In[37]:= Select[list, Mod[#, 2] == 0 &]
```

Out[37]=

$$\{2, 4, 6, 8, 10\}$$

```
In[38]:= list2 = {1, 2, 3, x, y, z, x^2, x^3}
```

Out[38]=

$$\{1, 2, 3, x, y, z, x^2, x^3\}$$

Cases[list2, _Integer]

Cases[list2, _^2]

Cases[list2, _^_]

Cases[list2, v | z]

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Lists.nb

Out[35]=

$$\{\{1, 2, 3\}, \{4, 5, 6\}, \{7, 8, 9\}\}$$

Selecting and Patterns

In[36]:= **Select**[list, # ≥ 5 &]

Out[36]=

$$\{5, 6, 7, 8, 9, 10\}$$

In[37]:= **Select**[list, Mod[#, 2] == 0 &]

Out[37]=

$$\{2, 4, 6, 8, 10\}$$

In[38]:= **list2** = {1, 2, 3, x, y, z, x², x³}

Out[38]=

$$\{1, 2, 3, x, y, z, x^2, x^3\}$$

In[39]:= **Cases**[list2, _Integer]

Out[39]=

$$\{1, 2, 3\}$$

Cases[list2, _[^]2]

Cases[list2, _[^]_]

Cases[list2, y | z]

Replacing

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Lists.nb

Out[35]=

$$\{\{1, 2, 3\}, \{4, 5, 6\}, \{7, 8, 9\}\}$$

Selecting and Patterns

In[36]:= **Select**[list, # ≥ 5 &]

Out[36]=

$$\{5, 6, 7, 8, 9, 10\}$$

In[37]:= **Select**[list, Mod[#, 2] == 0 &]

Out[37]=

$$\{2, 4, 6, 8, 10\}$$

In[38]:= **list2** = {1, 2, 3, x, y, z, x², x³}

Out[38]=

$$\{1, 2, 3, x, y, z, x^2, x^3\}$$

In[39]:= **Cases**[list2, _Integer]

Out[39]=

$$\{1, 2, 3\}$$

Cases[list2, _[^]2]

Cases[list2, _[^]_]

Cases[list2, y | z]

Replacing

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Selecting and Patterns

```
In[36]:= Select[list, # >= 5 &]
```

```
Out[36]= {5, 6, 7, 8, 9, 10}
```

```
In[37]:= Select[list, Mod[#, 2] == 0 &]
```

```
Out[37]= {2, 4, 6, 8, 10}
```

```
In[38]:= list2 = {1, 2, 3, x, y, z, x^2, x^3}
```

```
Out[38]= {1, 2, 3, x, y, z, x^2, x^3}
```

```
In[39]:= Cases[list2, _Integer]
```

```
Out[39]= {1, 2, 3}
```

```
In[40]:= Cases[list2, _^2]
```

```
Out[40]= {x^2}
```

```
Cases[list2, _^_]
```

```
Cases[list2, y | z]
```

Replacing

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Lists.nb

Out[39]=
 $\{1, 2, 3\}$

In[40]:= **Cases**[list2, _^2]

Out[40]=
 $\{x^2\}$

In[43]:= **x**^2 // **TreeForm**

Out[43]//TreeForm=

```
graph TD; Power[Power] --- x[x]; Power --- 2[2]
```

The diagram illustrates the internal structure of the expression x^2 as a tree. The root node is labeled 'Power'. It has two children: the variable 'x' on the left and the constant '2' on the right. All nodes are enclosed in yellow boxes.

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Lists.nb

```

In[36]:= Select[list, # > 5 &]
Out[36]=
{5, 6, 7, 8, 9, 10}

In[37]:= Select[list, Mod[#, 2] == 0 &]
Out[37]=
{2, 4, 6, 8, 10}

list2 = {1, 2, 3, x, y, z, x^2, x^3, x^2}
Out[38]=
{1, 2, 3, x, y, z, x^2, x^3}

In[39]:= Cases[list2, _Integer]
Out[39]=
{1, 2, 3}

In[40]:= Cases[list2, _^2]
Out[40]=
{x^2}

In[44]:= Cases[list2, _^_]
Out[44]=
{x^2, x^3}

Cases[list2, y | z]

```

Replacing

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Lists.nb

```

In[37]:= Select[list, Mod[#, 2] == 0 &]
Out[37]= {2, 4, 6, 8, 10}

In[45]:= list2 = {1, 2, 3, x, y, z, x^2, x^3, x^2 y}
Out[45]= {1, 2, 3, x, y, z, x^2, x^3, x^2 y}

In[46]:= Cases[list2, _Integer]
Out[46]= {1, 2, 3}

In[47]:= Cases[list2, _^2]
Out[47]= {x^2}

In[56]:= Cases[list2, (_^2) y_]
Out[56]= {x^2 y}

In[48]:= Cases[list2, _^_]
Out[48]= {x^2, x^3}

Cases[list2, y | z]

```

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Lists.nb

```

In[37]:= Select[list, Mod[#, 2] == 0 &]
Out[37]=
{2, 4, 6, 8, 10}

In[45]:= list2 = {1, 2, 3, x, y, z, x^2, x^3, x^2 y}
Out[45]=
{1, 2, 3, x, y, z, x^2, x^3, x^2 y}

In[46]:= Cases[list2, _Integer]
Out[46]=
{1, 2, 3}

In[47]:= Cases[list2, _^2]
Out[47]=
{x^2}

In[59]:= Cases[list2, (a_^2) b_]
Out[59]=
{x^2 y}

Groebner basis  curl  div  array rules  more...

In[58]:= Cases[list2, _^_]
Out[58]=
{x^2, x^3}

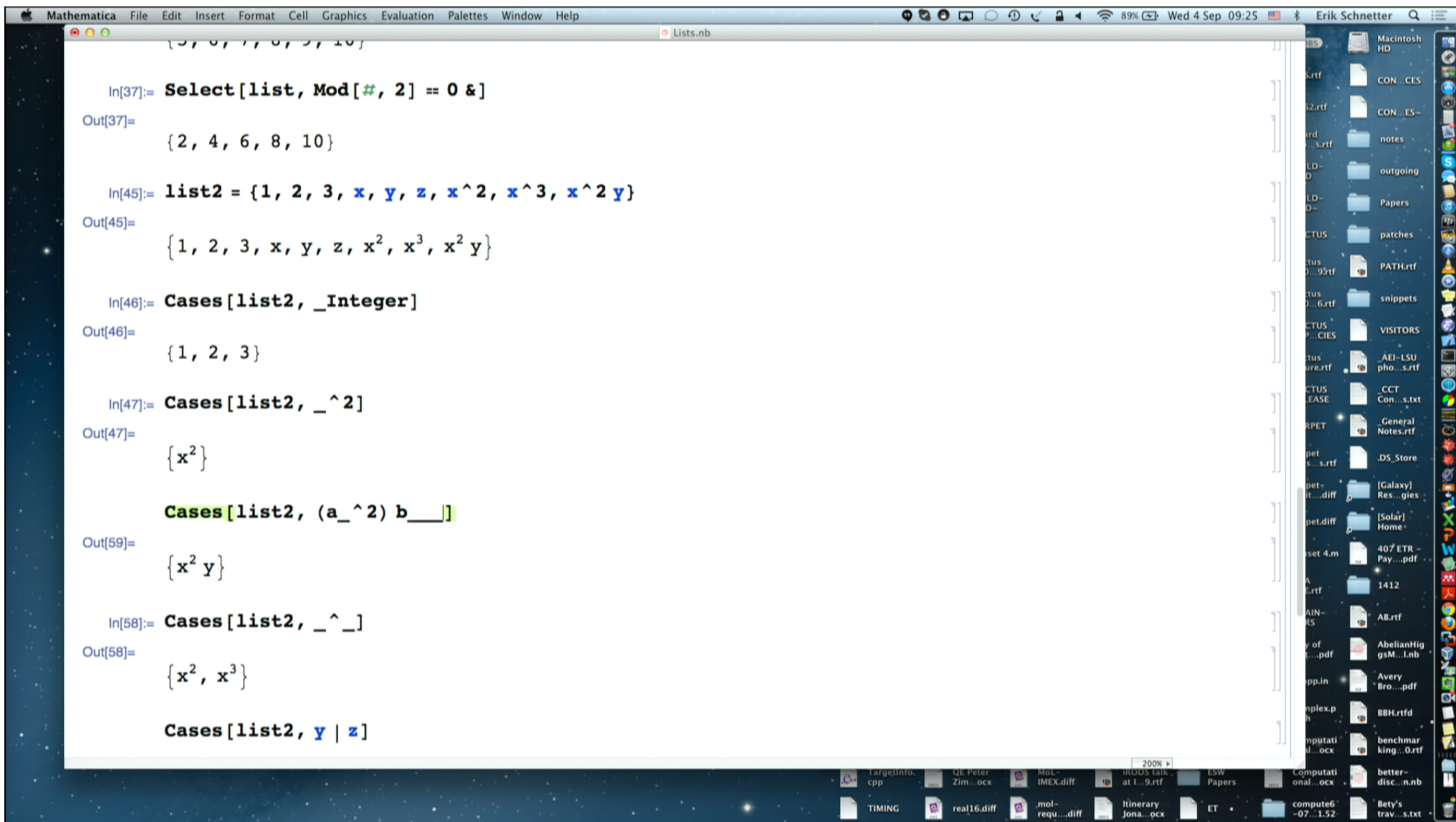
Cases[list2, y | z]

```

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Lists.nb

```

Out[45]=

$$\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$$


In[46]:= Cases[list2, _Integer]
Out[46]=

$$\{1, 2, 3\}$$


In[47]:= Cases[list2, _^2]
Out[47]=

$$\{x^2\}$$


In[61]:= Cases[list2, (a_^2) b_]
Out[61]=

$$\{x^2 y\}$$


In[58]:= Cases[list2, _^_]
Out[58]=

$$\{x^2, x^3\}$$


Cases[list2, y | z]

```

Replacing

```

list2 /. x → 4

list2 /. x^n_ → x^(n + 1)

```

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Lists.nb

$\{x^2\}$

In[61]:= Cases[list2, (a_^2) b_]

Out[61]= $\{x^2 y\}$

In[58]:= Cases[list2, _^_]

Out[58]= $\{x^2, x^3\}$

In[62]:= Cases[list2, y | z]

Out[62]= $\{y, z\}$

Replacing

In[63]:= list2

Out[63]= $\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$

In[64]:= list2 /. x → 4

Out[64]= $\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$

Groebner basis polynomial reduce polynomial GCD polynomial LCM more...

list2 /. x^n → x^(n+1)

200%

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Lists.nb

Out[61]=

$$\{x^2 y\}$$

In[58]:= Cases[list2, _^_]

Out[58]=

$$\{x^2, x^3\}$$

In[62]:= Cases[list2, y | z]

Out[62]=

$$\{y, z\}$$

Replacing

In[63]:= list2

Out[63]=

$$\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$$

In[64]:= list2 /. x → 4

Out[64]=

$$\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$$

In[65]:= list2 /. x^n_ → x^(n+1)

Out[65]=

$$\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$$

Groebner basis curl div polynomial reduce more...

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Lists.nb

Out[58]=

$$\{x^2, x^3\}$$

In[62]:= Cases[list2, y | z]

Out[62]=

$$\{y, z\}$$

Replacing

In[63]:= list2

Out[63]=

$$\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$$

In[64]:= list2 /. x → 4

Out[64]=

$$\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$$

In[65]:= list2 /. x^n_ → x^(n+1)

Out[65]=

$$\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$$

In[66]:= list2 /. n_Integer → 2 n

Out[66]=

$$\{2, 4, 6, x, y, z, x^4, x^6, x^4 y\}$$

Groebner basis curl div polynomial reduce more...

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Lists.nb

Out[62]=

$$\{y, z\}$$

Replacing

In[63]:= list2

Out[63]=

$$\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$$

In[64]:= list2 /. x → 4

Out[64]=

$$\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$$

In[65]:= list2 /. x^n_ → x^(n+1)

Out[65]=

$$\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$$

In[66]:= list2 /. n_Integer → 2 n

Out[66]=

$$\{2, 4, 6, x, y, z, x^4, x^6, x^4 y\}$$

In[67]:= list2 /. a_ → 2 a + 1

Out[67]=

$$\{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y\}$$

Groebner basis curl div polynomial reduce more...

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Lists.nb

Out[62]=

$$\{y, z\}$$

Replacing

In[63]:= list2

Out[63]=

$$\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$$

In[64]:= list2 /. x → 4

Out[64]=

$$\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$$

In[65]:= list2 /. x^n_ → x^(n+1)

Out[65]=

$$\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$$

In[66]:= list2 /. n_Integer → 2 n

Out[66]=

$$\{2, 4, 6, x, y, z, x^4, x^6, x^4 y\}$$

In[67]:= list2 /. a_ → 2 a + 1

Out[67]=

$$\{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y\}$$

Groebner basis curl div polynomial reduce more...

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Lists.nb

In[63]:= **list2**

Out[63]= $\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$

In[64]:= **list2 /. x → 4**

Out[64]= $\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$

In[65]:= **list2 /. xⁿ → x⁽ⁿ⁺¹⁾**

Out[65]= $\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$

In[66]:= **list2 /. n_Integer → 2 n**

Out[66]= $\{2, 4, 6, x, y, z, x^4, x^6, x^4 y\}$

In[67]:= **list2 /. a_ → 2 a + 1**

Out[67]= $\{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y\}$

list2 /. a_ /; a ≠ 1 → 0

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Lists.nb

In[63]:= **list2**

Out[63]= $\{1, 2, 3, x, y, z, x^2, x^3, x^2 y\}$

In[64]:= **list2 /. x → 4**

Out[64]= $\{1, 2, 3, 4, y, z, 16, 64, 16 y\}$

In[65]:= **list2 /. xⁿ → x⁽ⁿ⁺¹⁾**

Out[65]= $\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$

In[66]:= **list2 /. n_Integer → 2 n**

Out[66]= $\{2, 4, 6, x, y, z, x^4, x^6, x^4 y\}$

In[67]:= **list2 /. a_ → 2 a + 1**

Out[67]= $\{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y\}$

In[68]:= **list2 /. a_ /; a ≠ 1 → 0**

Out[68]= $\{1, 0, 0, x, y, z, 1, 1, y\}$

Groebner basis curl div polynomial reduce more...

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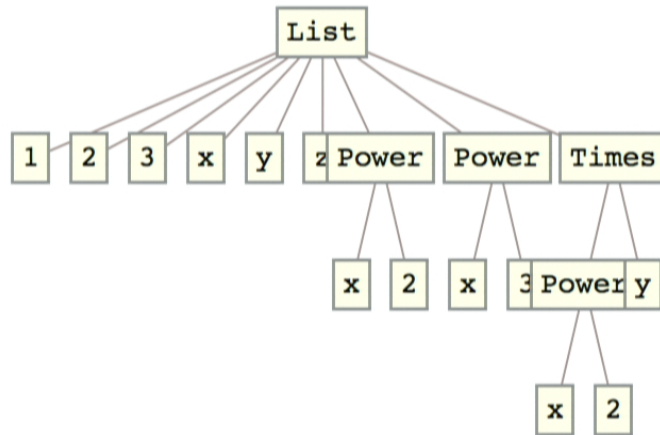
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Replacing

```
In[69]:= list2 // TreeForm
```

```
Out[69]//TreeForm=
```



```
In[64]:= list2 /. x -> 4
```

```
Out[64]=
```

```
{1, 2, 3, 4, y, z, 16, 64, 16 y}
```

```
In[65]:= list2 /. x^n_ -> x^(n+1)
```

```
Out[65]=
```

```
{1, 2, 3, x, y, z, x^3, x^4, x^3 y}
```

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Lists.nb

```
In[62]:= Cases[list2, y | z]
```

```
Out[62]= {y, z}
```

Replacing

```
In[71]:= list2 // TreeForm
```

```
Out[71]//TreeForm=
```

Groebner basis polynomial reduce polynomial GCD polynomial LCM more...

```
In[64]:= list2 /. x -> 4
```

```
Out[64]= {1, 2, 3, 4, y, z, 16, 64, 16 y}
```

```
In[65]:= list2 /. x^n_ -> x^(n+1)
```

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Lists.nb

In[65]:= `list2 /. x^n_ -> x^(n + 1)`

Out[65]= $\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$

In[72]:= `list2 /. n_Integer -> 2 n`

Out[72]= $\{2, 4, 6, x, y, z, x^4, x^6, x^4 y, y_{16}\}$

In[73]:= `list2 /. a_ -> 2 a + 1`

Out[73]= $\{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y, 1 + 2 y_8\}$

In[68]:= `list2 /. a_ /; a != 1 -> 0`

Out[68]= $\{1, 0, 0, x, y, z, 1, 1, y\}$

//.

`list3 = {x, f[x], f[f[x]}`

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Lists.nb

Out[65]=

$$\{1, 2, 3, x, y, z, x^3, x^4, x^3 y\}$$

In[72]:= `list2 /. n_Integer -> 2 n`

Out[72]=

$$\{2, 4, 6, x, y, z, x^4, x^6, x^4 y, y_{16}\}$$

In[73]:= `list2 /. a_ -> 2 a + 1`

Out[73]=

$$\{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y, 1 + 2 y_8\}$$

In[68]:= `list2 /. a_ /; a != 1 -> 0`

Out[68]=

$$\{1, 0, 0, x, y, z, 1, 1, y\}$$

//.

In[75]:= `list3 = {x, f[y], f[f[z]], f[f[f[a]]]}`

Out[75]=

$$\{x, f[y], f[f[z]], f[f[f[a]]]\}$$

In[76]:= `list3 /. f[q_] -> Sin[q]`

Out[76]=

$$\{x, \sin[y], \sin[f[z]], \sin[f[f[a]]]\}$$

partition... reverse all subsets permutations more...

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Lists.nb

```

In[73]:= list2 /. a_ -> 2 a + 1
Out[73]=
{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y, 1 + 2 y^8}

In[68]:= list2 /. a_ /; a != 1 -> 0
Out[68]=
{1, 0, 0, x, y, z, 1, 1, y}

//.

In[75]:= list3 = {x, f[y], f[f[z]], f[f[f[a]]]}
Out[75]=
{x, f[y], f[f[z]], f[f[f[a]]]}

In[76]:= list3 /. f[q] -> Sin[q]
Out[76]=
{x, Sin[y], Sin[f[z]], Sin[f[f[a]]]}

In[77]:= list3 //. f[q] -> Sin[q]
Out[77]=
{x, Sin[y], Sin[Sin[z]], Sin[Sin[Sin[a]]]}

In[78]:= list3 /. f[q] -> Sin[q] /. f[q] -> Sin[q]
Out[78]=
{x, Sin[y], Sin[Sin[z]], Sin[Sin[f[a]]]}

```

partition... reverse all subsets permutations more...

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Lists.nb

```

In[73]:= list2 /. a_ -> 2 a + 1
Out[73]=
{3, 5, 7, 1 + 2 x, 1 + 2 y, 1 + 2 z, 1 + 2 x^2, 1 + 2 x^3, 1 + 2 x^2 y, 1 + 2 y^8}

In[68]:= list2 /. a_ /; a != 1 -> 0
Out[68]=
{1, 0, 0, x, y, z, 1, 1, y}

//.

In[75]:= list3 = {x, f[y], f[f[z]], f[f[f[a]]]}
Out[75]=
{x, f[y], f[f[z]], f[f[f[a]]]}

In[76]:= list3 /. f[q] -> Sin[q]
Out[76]=
{x, Sin[y], Sin[f[z]], Sin[f[f[a]]]}

In[77]:= list3 //. f[q] -> Sin[q]
Out[77]=
{x, Sin[y], Sin[Sin[z]], Sin[Sin[Sin[a]]]}

In[80]:= list3 /. f[q] -> Sin[q] /. f[q] -> Sin[q] /. f[q] -> Sin[q] /. f[q] -> Sin[q]
Out[80]=
{x, Sin[y], Sin[Sin[z]], Sin[Sin[Sin[a]]]}

```

partition... reverse all subsets permutations more...

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Avery Bro...pdf

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BBH.rtf

benchmark king...0.rtf

better-disc...n.nb

Bety's trav...s.txt

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Running...CurrentImage.nb

Fun with CurrentImage

```
In[81]:= CurrentImage[]

CurrentImage[3]

ListAnimate[CurrentImage[30]]
```

@@ Notation

```
list = {Sin[x], x}

D @@ list

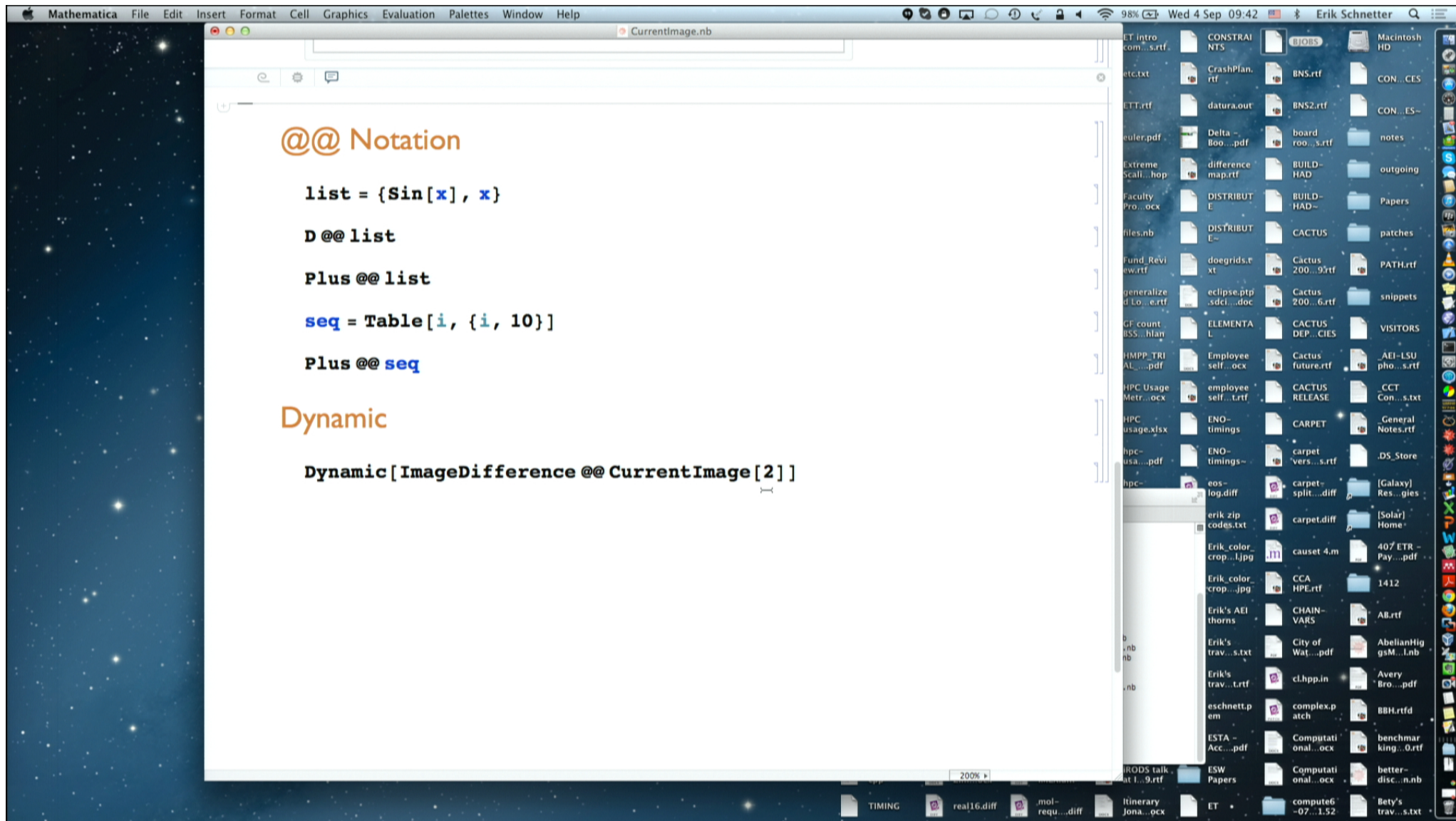
Plus @@ list

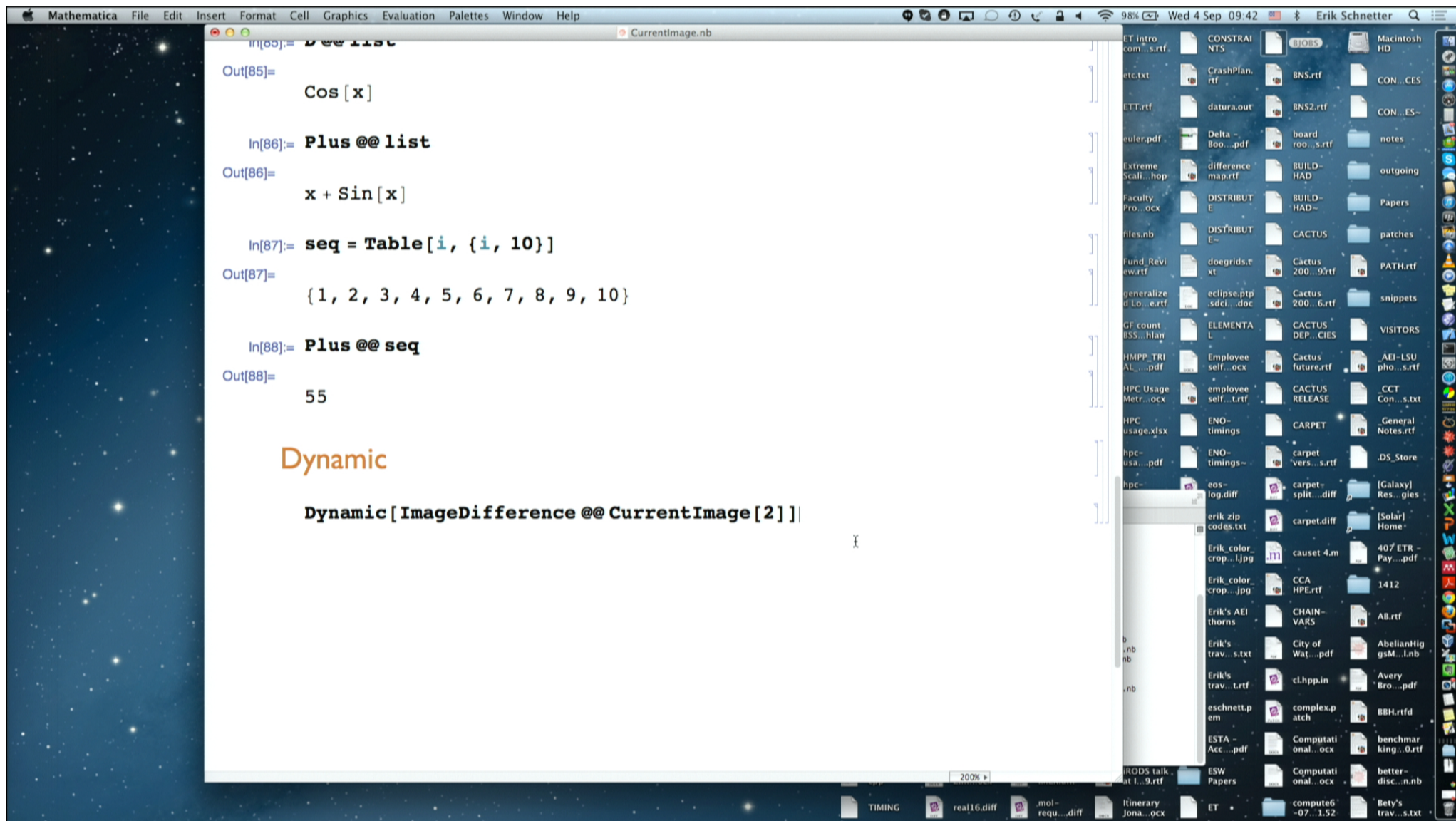
seq = Table[i, {i, 10}]

Plus @@ seq
```

Dynamic

```
Dynamic[ImageDifference @@ CurrentImage[2]]
```





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CurrentImage.nb

```

Out[86]=
  x + Sin[x]

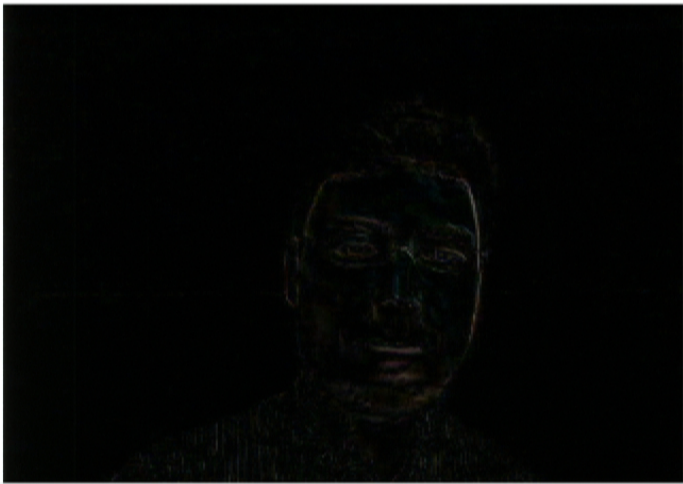
In[87]:= seq = Table[i, {i, 10}]
Out[87]=
  {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}

In[88]:= Plus @@ seq
Out[88]=
  55

Dynamic

In[89]:= Dynamic[ImageDifference @@ CurrentImage[2]]
Out[89]=

```



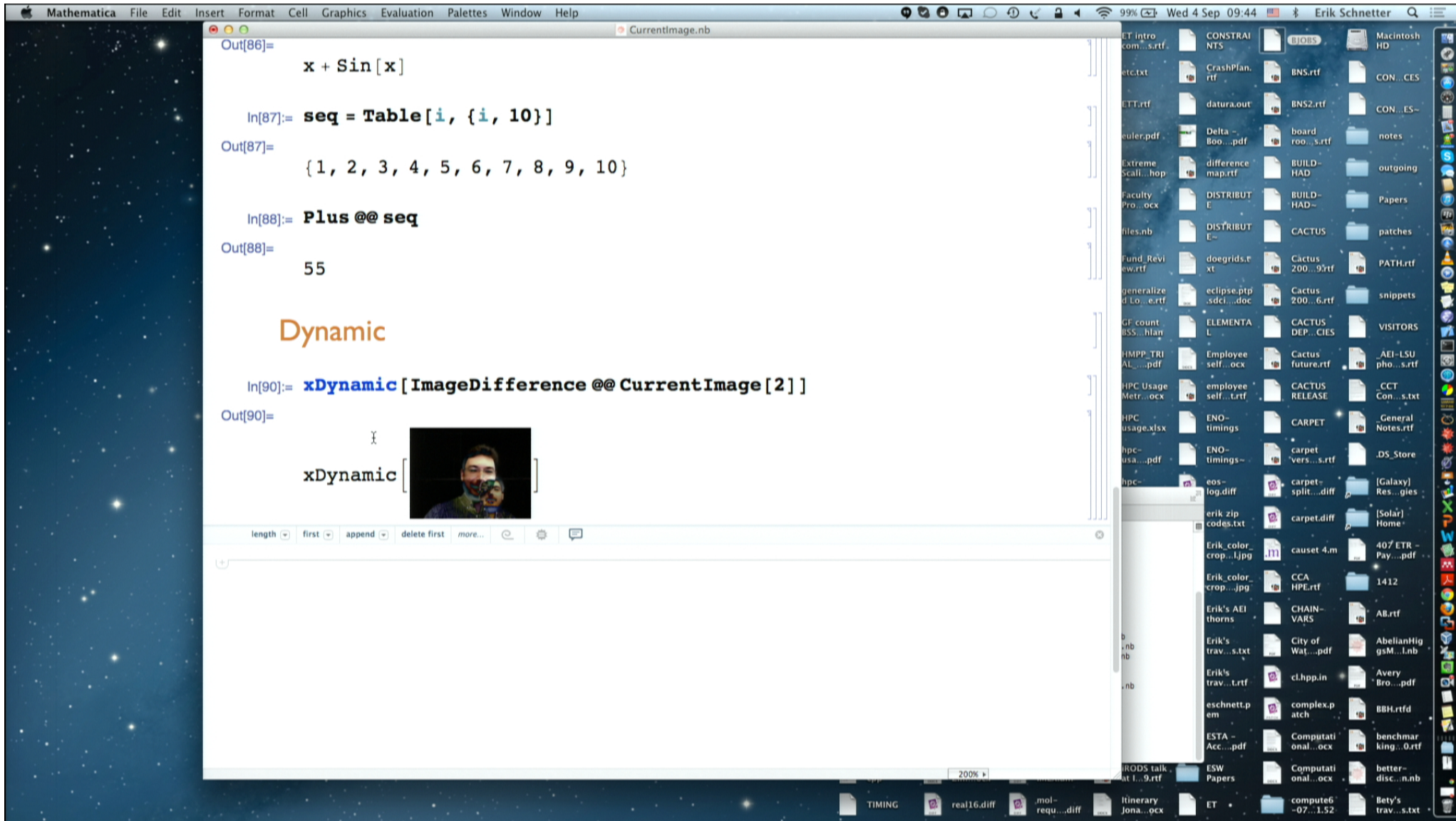
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Desktop background: A blue space-themed wallpaper with stars and galaxies.

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- carpet-split...
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- AbelianHig...
- Erik's trav...
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- eschnepp...
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- BBH.rtf
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- Bety's trav...

Taskbar (left to right): TIMING, real16.diff, .mol-requ..., Itinerary Jona..., ET, compute6...



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CurrentImage.nb

```

Out[86]=
  x + Sin[x]

In[87]:= seq = Table[i, {i, 10}]
Out[87]=
  {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}

In[88]:= Plus @@ seq
Out[88]=
  55

Dynamic

In[90]:= xDynamic[ImageDifference @@ CurrentImage[2]]
Out[90]=
  xDynamic[]

In[91]:= Sin[1, 1]
Sin::argx : Sin called with 2 arguments; 1 argument is expected. >>

Out[91]=
  Sin[1, 1]

```

numerical value integer part root approximant

200%

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 GF count...BSS...hlan ELEMENTA...L CACTUS DEP...CIES VISITORS
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 HPC Usage...Metr...ocx employee...self...l.rtf CACTUS RELEASE CCT Con...s.txt
 HPC...usage.xlsx ENO...timings CARPET General Notes.rtf
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Gamma Matrices.nb

Algebra of γ Matrices

```

SetAttributes[ $\delta$ , Orderless];

NumQ[x_?NumericQ] = True;
NumQ[ $\delta$ [x_, y_]] = True;
NumQ[x_] = False;

rules =
{
  c__ .  $\gamma$ [a_] .  $\gamma$ [b_] . d__  $\Rightarrow$  c . (- $\gamma$ [b] .  $\gamma$ [a] + 2  $\delta$ [a, b]) . d /;
    Not@OrderedQ[{a, b}],
  c__ .  $\gamma$ [a_] .  $\gamma$ [a_] . d__  $\Rightarrow$  c .  $\delta$ [a, a] . d,
  a1__ . a2__ . a3__  $\Rightarrow$  a2 a1 . a3 /; NumQ[a2],
  a1__ . (a2 a4__) . a3__  $\Rightarrow$  a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__  $\Rightarrow$  a1 . a2 . a3 + a1 . a4 . a3,
  CenterDot[a_]  $\Rightarrow$  Flatten[CenterDot[a]],
   $\delta$ [c_, c_]  $\rightarrow$  dim,
   $\delta$ [c_, d_]^2  $\rightarrow$  dim,
   $\delta$ [a1_, a2_] a3_  $\Rightarrow$  (a3 /. a1  $\rightarrow$  a2) /; Not@FreeQ[a3, a1]};

```

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```

~$ cd /home/eschnett/staff/200923/Sep/3/1312/psi12.nb
~$ cd /home/eschnett/staff/200923/Sep/3/1312/psi12.nb
eschnett@Redshift:~/txt/Talks/Psi2013 (09:35:40)
$ open CurrentImage.nb
eschnett@Redshift:~/txt/Talks/Psi2013 (09:40:55)
$ open Gamma\Matrices.nb
eschnett@Redshift:~/txt/Talks/Psi2013 (09:45:54)
$

```

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Gamma Matrices.nb
99%
Wed 4 Sep 09:46
Erik Schnetter

Algebra of γ Matrices

```

SetAttributes[ $\delta$ , Orderless];

NumQ[x_?NumericQ] = True;
NumQ[ $\delta$ [x_, y_]] = True;
NumQ[x_] = False;

rules =
{
  c__ .  $\gamma$ [a_] .  $\gamma$ [b_] . d__  $\Rightarrow$  c . (- $\gamma$ [b] .  $\gamma$ [a] + 2  $\delta$ [a, b]) . d /;
    Not@OrderedQ[{a, b}],
  c__ .  $\gamma$ [a_] .  $\gamma$ [a_] . d__  $\Rightarrow$  c .  $\delta$ [a, a] . d,
  a1__ . a2__ . a3__  $\Rightarrow$  a2 a1 . a3 /; NumQ[a2],
  a1__ . (a2 a4__) . a3__  $\Rightarrow$  a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__  $\Rightarrow$  a1 . a2 . a3 + a1 . a4 . a3,
  CenterDot[a_]  $\Rightarrow$  Flatten[CenterDot[a]],
   $\delta$ [c_, c_]  $\rightarrow$  dim,
   $\delta$ [c_, d_]  $\rightarrow$  dim,
   $\delta$ [a1_, a2_] a3_  $\Rightarrow$  (a3 /. a1  $\rightarrow$  a2) /; Not@FreeQ[a3, a1]
};

 $\gamma$ [d] .  $\gamma$ [a] .  $\gamma$ [c] .  $\gamma$ [b] .  $\gamma$ [d] .  $\gamma$ [c] .  $\gamma$ [a] //. rules /. CenterDot[ $\gamma$ [a_]]  $\rightarrow$   $\gamma$ [a] //
Simplify

- (-16 + 24 dim - 10 dim2 + dim3)  $\gamma$ [b]

```

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Gamma Matrices.nb

Algebra of γ Matrices

```

SetAttributes[ $\delta$ , Orderless];

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  a1__ . (a2 a4__) . a3__  $\Rightarrow$  a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__  $\Rightarrow$  a1 . a2 . a3 + a1 . a4 . a3,
  CenterDot[a_]  $\Rightarrow$  Flatten[CenterDot[a]],
   $\delta$ [c_, c_]  $\rightarrow$  dim,
   $\delta$ [c_, d_]  $\rightarrow$  dim,
   $\delta$ [a1_, a2_] a3_  $\Rightarrow$  (a3 /. a1  $\rightarrow$  a2) /; Not@FreeQ[a3, a1]};

In[92]:= Plus[y, x] // FullForm

Out[92]//FullForm=
Plus[x, y]

```

3D plot x derivative x integral global max more...

200%

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Algebra of γ Matrices

```

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NumQ[ $\delta$ [x_, y_]] = True;
NumQ[x_] = False;

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{
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    Not@OrderedQ[{a, b}],
  c__ .  $\gamma$ [a_] .  $\gamma$ [a_] . d__  $\Rightarrow$  c .  $\delta$ [a, a] . d,
  a1__ . a2__ . a3__  $\Rightarrow$  a2 a1 . a3 /; NumQ[a2],
  a1__ . (a2 a4__) . a3__  $\Rightarrow$  a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__  $\Rightarrow$  a1 . a2 . a3 + a1 . a4 . a3,
  CenterDot[a_]  $\Rightarrow$  Flatten[CenterDot[a]],
   $\delta$ [c_, c_]  $\rightarrow$  dim,
   $\delta$ [c_, d_]  $\rightarrow$  dim,
   $\delta$ [a1_, a2_] a3_  $\Rightarrow$  (a3 /. a1  $\rightarrow$  a2) /; Not@FreeQ[a3, a1]};

In[94]:= CenterDot[y, x, y]

Out[94]= y . x . y

```


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Gamma Matrices.nb

Algebra of γ Matrices

```

SetAttributes[ $\delta$ , Orderless];

NumQ[x_?NumericQ] = True;
NumQ[ $\delta$ [x_, y_]] = True;
NumQ[x_] = False;

rules =
{
  c__ .  $\gamma$ [a_] .  $\gamma$ [b_] . d__  $\Rightarrow$  c . (- $\gamma$ [b] .  $\gamma$ [a] + 2  $\delta$ [a, b]) . d /;
    Not@OrderedQ[{a, b}],
  c__ .  $\gamma$ [a_] .  $\gamma$ [a_] . d__  $\Rightarrow$  c .  $\delta$ [a, a] . d,
  a1__ . a2__ . a3__  $\Rightarrow$  a2 a1 . a3 /; NumQ[a2],
  a1__ . (a2 a4__) . a3__  $\Rightarrow$  a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__  $\Rightarrow$  a1 . a2 . a3 + a1 . a4 . a3,
  CenterDot[a_]  $\Rightarrow$  Flatten[CenterDot[a]],
   $\delta$ [c_, c_]  $\rightarrow$  dim,
   $\delta$ [c_, d_]^2  $\rightarrow$  dim,
   $\delta$ [a1_, a2_] a3_  $\Rightarrow$  (a3 /. a1  $\rightarrow$  a2) /; Not@FreeQ[a3, a1]};

In[94]:= CenterDot[y, x, y]

Out[94]= y . x . y

```

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Erik Schnetter

```

NumQ[x_] = False;

rules =
{
  c__ . γ[a_] . γ[b_] . d__ => c . (-γ[b] . γ[a] + 2 δ[a, b]) . d /;
    Not@OrderedQ[{a, b}],
  c__ . γ[a_] . γ[a_] . d__ => c . δ[a, a] . d,
  a1__ . a2__ . a3__ => a2 a1 . a3 /; NumQ[a2],
  a1__ . (a2_ a4_) . a3__ => a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__ => a1 . a2 . a3 + a1 . a4 . a3,
  CenterDot[a_] => Flatten[CenterDot[a]],
  δ[c_, c_] -> dim,
  δ[c_, d_]^2 -> dim,
  δ[a1_, a2_] a3_ => (a3 /. a1 -> a2) /; Not@FreeQ[a3, a1]};

In[100]:=
γ[d] . γ[a] . γ[c] . γ[b] . γ[d] . γ[c] . γ[a] //. rules /. CenterDot[γ[a_]] -> γ[a] //
Simplify

Out[100]:=
- (-16 + 24 dim - 10 dim^2 + dim^3) γ[b]

```

b derivative
b integral
expand
inverse function

Deck of cards

```

Hearts = Style[♥, {Red, Large}];
Clubs = Style[♣, Large];

```

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Erik Schnetter

```

NumQ[x_] = False;

rules =
{
  c__ . γ[a_] . γ[b_] . d__ => c . (-γ[b] . γ[a] + 2 δ[a, b]) . d /;
    Not@OrderedQ[{a, b}],
  c__ . γ[a_] . γ[a_] . d__ => c . δ[a, a] . d,
  a1__ . a2__ . a3__ => a2 a1 . a3 /; NumQ[a2],
  a1__ . (a2_ a4_) . a3__ => a2 a1 . a4 . a3 /; NumQ[a2],
  a1__ . (a2_ + a4_) . a3__ => a1 . a2 . a3 + a1 . a4 . a3,
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  δ[c_, d_]^2 -> dim,
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In[100]:=
γ[d] . γ[a] . γ[c] . γ[b] . γ[d] . γ[c] . γ[a] //. rules /. CenterDot[γ[a_]] -> γ[a] //
Simplify

Out[100]:=
- (-16 + 24 dim - 10 dim^2 + dim^3) γ[b]

```

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Gamma Matrices.nb

Algebra of γ Matrices

$a \Rightarrow b$

```

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   $\delta$ [c_, c_]  $\rightarrow$  dim,
   $\delta$ [c_, d_]  $\rightarrow$  dim,

```

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```

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eschnett@redshift:~/txt/Talks/Psi2013 (09:40:55)
$ open Gamma Matrices.nb
eschnett@redshift:~/txt/Talks/Psi2013 (09:45:54)
$ open Gamma Matrices.nb
eschnett@redshift:~/txt/Talks/Psi2013 (09:50:30)
$

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Watchdog Timers

This is a slow function: It returns its argument after waiting for that many seconds

```
In[101]:= fslow[i_] := (Pause[i]; i)
```

This takes 3 seconds:

```
fslow[3]
```

We now create a table of 10 entries. We wait at most 5 seconds for each entry, and if there is no result by that time, we use the value 0 instead. By definition, this calculation takes at most 50 seconds.

```
Table[TimeConstrained[fslow[i], 5, 0], {i, 10}]
```

Execution times (from a scrollable window):

- 07:39 CurrentImage.nb
- 08:10 Gamma Matrices.nb
- 16:50 Heat Equation.nb
- 09:35 Lists.nb
- 16:46 Mandelbrot.nb
- 00:44 Remote Kernels.nb
- 16:48 Watchdog.nb
- 15:32 psi1.nb
- 15:32 psi2.nb
- 48)
- 55)
- 54)
- 38)
- 56)

Watchdog Timers

This is a slow function: It returns its argument after waiting for that many seconds

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```

This takes 3 seconds:

```
In[102]:=
fslow[3]
```

```
Out[102]=
3
```

We now create a table of 10 entries. We wait at most 5 seconds for each entry, and if there is no result by that time, we use the value 0 instead. By definition, this calculation takes at most 50 seconds.

```
Table[TimeConstrained[fslow[i], 5, 0], {i, 10}]
```

The file explorer window on the right shows a list of files and folders, including:

- Itinerary Jona...pdf
- ET intro com...s.rtf
- CONSTRAI NTS
- BIOS
- Macintosh HD
- etc.txt
- CrashPlan. rtf
- BNS.rtf
- CON...CES
- ETT.rtf
- datura.out
- BNS2.rtf
- CON...ES-
- euler.pdf
- Delta ...pdf
- board roo...s.rtf
- notes
- Extreme Scali...hop
- difference map.rtf
- BUILD-HAD
- outgoing
- Faculty Pro...ocx
- DISTRIBUT E
- BUILD-HAD~
- Papers
- files.nb
- DISTRIBUT E~
- CACTUS
- patches
- Fund_Revi ew.rtf
- doegrids.r xt
- Cactus 200...9s.rtf
- PATH.rtf
- generalize d Lo...e.rtf
- eclipse.ptp
- Cactus 200...6.rtf
- snippets
- GF count BSS...hlan
- ELEMENTA L
- CACTUS DEP...CIES
- VISITORS
- HMPP_TRI AL...pdf
- Employee self...ocx
- Cactus future.rtf
- AEI-LSU pho...s.rtf
- HPCC Usage Metr...ocx
- employee self...l.rtf
- CACTUS RELEASE
- CCT Con...s.txt
- hpc-usage.xlsx
- ENO-timings
- CARPET
- General Notes.rtf
- hpc-...pdf
- ENO-timings~
- carpet vers...s.rtf
- .DS_Store
- hpc-...pdf
- eos-log.diff
- carpet-split...diff
- [Galaxy] Res...gies
- erik zip codes.txt
- carpet.diff
- [Solar] Home
- erik_color_crop...l.jpg
- causet 4.m
- 407 ETR - Pay...pdf
- CurrentImage.nb
- Gamma Matrices.nb
- Heat Equation.nb
- Lists.nb
- Mandelbrot.nb
- Remote Kernels.nb
- Watchdog.nb
- psi1.nb
- psi2.nb
- CCCA HPE.rtf
- CHAIN-VARS
- AB.rtf
- City of Wat...pdf
- AbelianHig gsM...Ln
- cl.hpp.in
- Avery Bro...pdf
- eschnepp am
- complex.p atch
- BBH.rtf
- ESTA - Acc...pdf
- Computati onal...ocx
- benchmar king...0.rtf
- Computati onal...ocx
- better-disc...n.nb
- compute6 -07...1.52
- Bety's trav...s.txt

Mandelbrot Set

(mostly taken from *Mathematica's* documentation)

Mandelbrot function for a single point

```
mcf = Compile[{{c, _Complex}},  
  Module[{n = 0, z = 0. + 0. i, maxn = 1000},  
    While[n < maxn && Re[z]^2 + Im[z]^2 < 4, z = z^2 + c; n++]; If[n == maxn, 0, n],  
  RuntimeOptions -> "Speed", CompilationTarget -> "C"];
```

Colourmap

```
colormap = (If[#1 == 0, {0., 0., 0.}, r[[#1]] &] /. r -> RandomReal[1, {1000, 3}];
```

Grid of points

```
cpoints = Compile[{{xmin, _Real}, {xmax, _Real}, {nx, _Integer},  
  {ymin, _Real}, {ymax, _Real}, {ny, _Integer}},  
  Table[x + i y, {y, ymin, ymax,  $\frac{ymax - ymin}{ny - 1}$ }, {x, xmin, xmax,  $\frac{xmax - xmin}{nx - 1}$ }]];
```

Mandelbrot function for all points

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help Numerical Examples - Wolfram Mathematica

LibraryLink/tutorial/Numerical

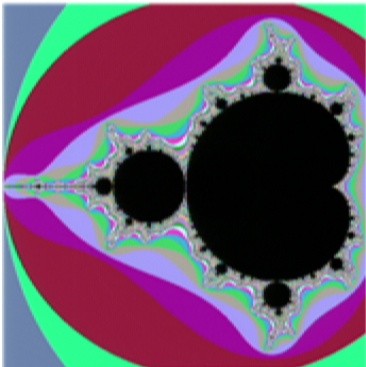
Wolfram LibraryLink

This gives the total time taken to make a 512×512 image of the Mandelbrot set.

```
In[13]:=
AbsoluteTiming[Graphics[mimage[{-2., .5, n}, {-1.25, 1.25, n}]]]
```

Out[13]=

{0.6080000,



The timing for getting the whole image using these compiled functions is faster than it was for just evaluating the function at the sample points. This is because much of the time shown for evaluating the sample points above was spent in actually constructing the `Table` as a `List` instead of a `PackedArray`; with the compiled functions, packed arrays are used throughout.

If you have a machine with several cores, the computation can be made even faster by using parallelization.

This redefines the `CompiledFunction` for computing the color channels to use parallelization.

```
In[14]:=
cmf = With[{f = mlf, c = colormap},
  Compile[{{x, _Complex}}, c[f[x]], RuntimeAttributes -> Listable, Parallelization -> True]];
```

200%

Mandelbrot Set

(mostly taken from *Mathematica's* documentation)

Mandelbrot function for a single point

```
In[1]:= mcf = Compile[{{c, _Complex}}, Module[{n = 0, z = 0. + 0. i, maxn = 1000},  
    While[n < maxn && Re[z]^2 + Im[z]^2 < 4, z = z^2 + c; n++]; If[n == maxn, 0, n]], RuntimeOptions -> "Speed",  
    CompilationTarget -> "C"];
```

CCompilerDriver`CreateLibrary::cmperr : Compile error: clang: error: no such file or directory: '9.0.1.app/SystemFiles/IncludeFiles/C' >>

CCompilerDriver`CreateLibrary::cmperr :

Compile error: clang: error: no such file or directory: '9.0.1.app/SystemFiles/Links/MathLink/DeveloperKit/MacOSX-x86-64/CompilerAdditions' >>

Compile::nogen : A library could not be generated from the compiled function. >>

Colourmap

```
In[2]:= colormap = (If[#1 == 0, {0., 0., 0.}, r[[#1]]] &) /. r -> RandomReal[1, {1000, 3}];
```

Grid of points

```
In[3]:= cpoints = Compile[{{xmin, _Real}, {xmax, _Real}, {nx, _Integer}, {ymin, _Real}, {ymax, _Real}, {ny, _Integer}},  
    Table[x + i y, {y, ymin, ymax,  $\frac{ymax - ymin}{ny - 1}$ }, {x, xmin, xmax,  $\frac{xmax - xmin}{nx - 1}$ }}];
```


$$x_0 = 0$$

$$x_{n+1} = x_n^2 + c$$

Mandelbrot Set

(mostly taken from *Mathematica's* documentation)

Mandelbrot function for a single point

```
In[1]:= mcf = Compile[{{c, _Complex}}, Module[{n = 0, z = 0. + 0. i, maxn = 1000},  
    While[n < maxn && Re[z]^2 + Im[z]^2 < 4, z = z^2 + c; n++]; If[n == maxn, 0, n], RuntimeOptions -> "Speed",  
    CompilationTarget -> "C"];
```

CCompilerDriver`CreateLibrary::cmperr : Compile error: clang: error: no such file or directory: '9.0.1.app/SystemFiles/IncludeFiles/C' >>

CCompilerDriver`CreateLibrary::cmperr :

Compile error: clang: error: no such file or directory: '9.0.1.app/SystemFiles/Links/MathLink/DeveloperKit/MacOSX-x86-64/CompilerAdditions' >>

Compile::nogen : A library could not be generated from the compiled function. >>

Colourmap

```
In[2]:= colormap = (If[#1 == 0, {0., 0., 0.}, r[[#1]]] &) /. r -> RandomReal[1, {1000, 3}];
```

Grid of points

```
In[3]:= cpoints = Compile[{{xmin, _Real}, {xmax, _Real}, {nx, _Integer}, {ymin, _Real}, {ymax, _Real}, {ny, _Integer}},  
    Table[x + i y, {y, ymin, ymax,  $\frac{ymax - ymin}{ny - 1}$ }, {x, xmin, xmax,  $\frac{xmax - xmin}{nx - 1}$ }]];
```

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Mandelbrot.nb

```

];
img = mimagecf[{xlo, xhi, nx}, {ylo, yhi, ny}];
getImage = False;
];
Show[Graphics[{img, If[TrueQ[box], {Opacity[.5], Yellow, Rectangle[dragstart, dragval]}, {}]}],
  ImageSize -> {nx, ny}]],
"MouseDown" -> (dragval = dragstart = MousePosition["Graphics"];
  If[pan, blo = {xlo, ylo}; bhi = {xhi, yhi}, box = True]),
"MouseDragged" -> (dragval = MousePosition["Graphics"]; getBB = pan; getImage = pan),
"MouseUp" -> (box = False; getBB = True; getImage = True)]
]]]

```

In[8]:= mandelPlot[{-2.5, .5, 500}, {-1.25, 1.25, 500}]

Out[8]=

s_x 0.477121

s_y 0.39794

Click to Pan

Drag in image to select new frame

\$Aborted

200%

The types of the two results in `If[Compile`FunctionVariable$5325 == 0, {0., 0., 0.}, {{0.0560901, 0.675281, 0.991481}, <<49>>, <<950>>}]<<29>>]]` are incompatible because their ranks are different. Evaluation will use the uncompiled function. >>

Test call

```
In[6]:= AbsoluteTiming[mimagecf[{-2., .5, 500}, {-1.25, 1.25, 500}];]
```

CompiledFunction::pext : Instruction 1 in
CompiledFunction[{8, 9., 5852}, {_Complex}, {{4, 0, 0}, {3, 0, 0}}, <<1>>, <<1>>, {<<1>>}, Function[{x}, (If[<<1>>] &)[Evaluate[x]], Listable], Evaluate]
calls ordinary Mathematica code that can be evaluated on only one thread at a time. >>

Part::pspec : Part specification -2. - 1.25 i is neither a machine-sized integer nor a list of machine-sized integers. >>

CompiledFunction::cfse : Compiled expression {{0.0560901, 0.675281, 0.991481}, <<49>>, <<950>>}]<<-2. - 1.25 i>> should be a machine-size real number. >>

Part::pspec : Part specification -2. - 0.623747 i is neither a machine-sized integer nor a list of machine-sized integers. >>

CompiledFunction::cfse :
Compiled expression {{0.0560901, 0.675281, 0.991481}, <<49>>, <<950>>}]<<-2. - 0.623747 i>> should be a machine-size real number. >>

Part::pspec : Part specification -0.747495 - 0.313126 i is neither a machine-sized integer nor a list of machine-sized integers. >>

General::stop : Further output of Part::pspec will be suppressed during this calculation. >>

CompiledFunction::cfse :
Compiled expression {{0.0560901, 0.675281, 0.991481}, <<49>>, <<950>>}]<<-0.747495 - 0.313126 i>> should be a machine-size real number. >>

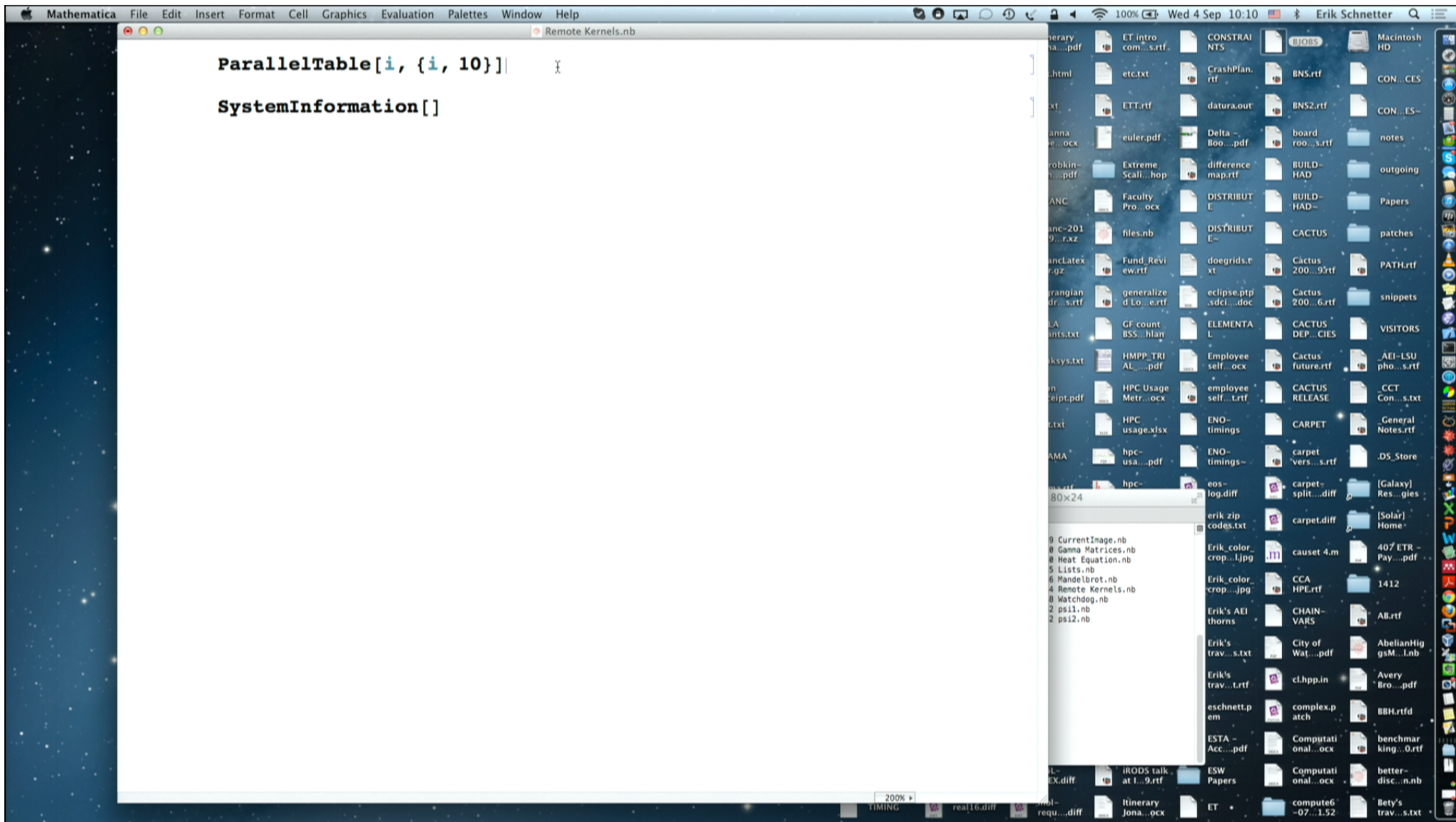
General::stop : Further output of CompiledFunction::cfse will be suppressed during this calculation. >>

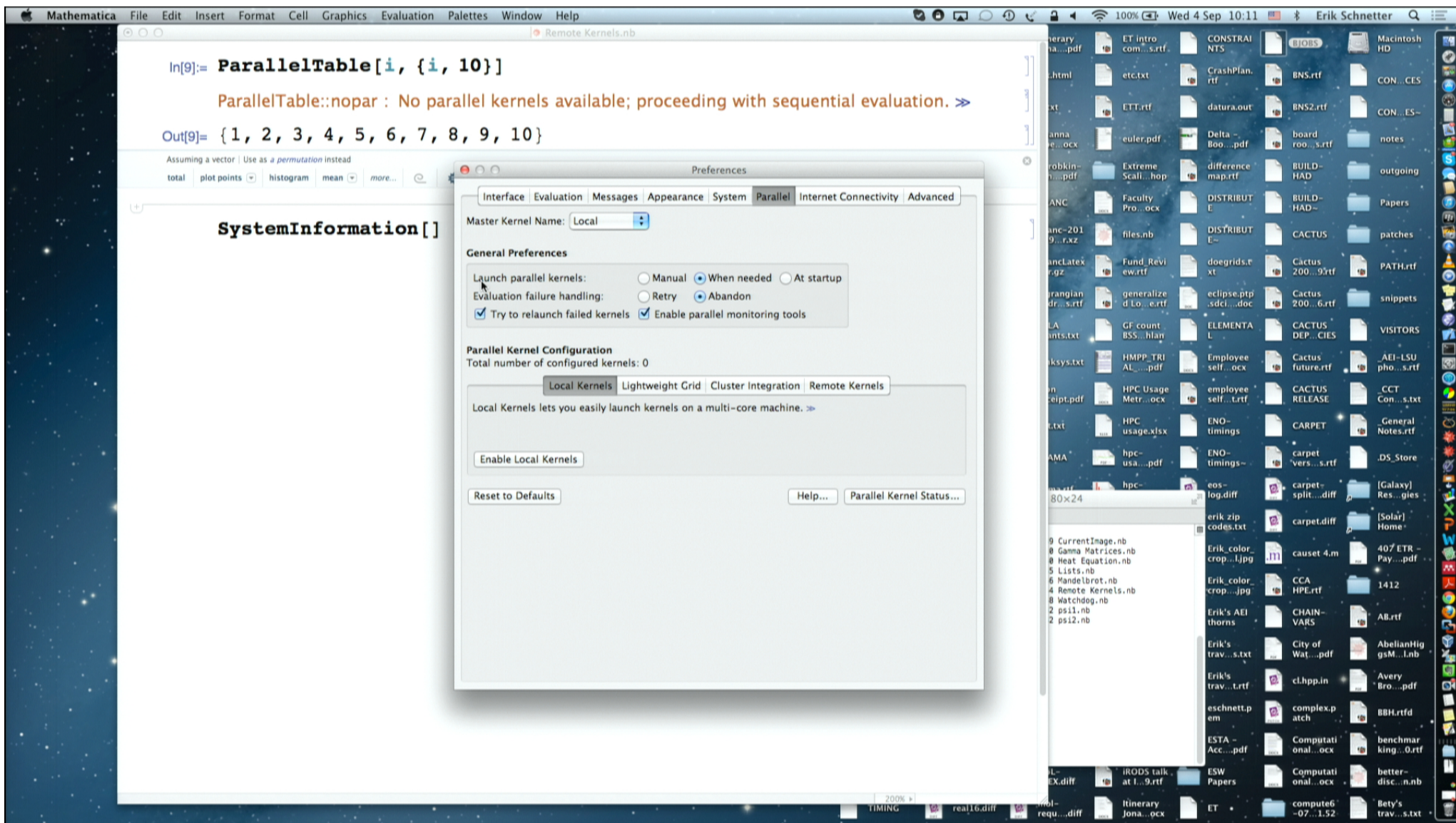
CompiledFunction::cfexe : Could not complete external evaluation; proceeding with uncompiled evaluation. >>

```
Out[6]= {9.735866, Null}
```

Define a nice user interface

```
In[7]:= mandelPlot[{x0_, x1_, nx_}, {y0_, y1_, ny_}] :=  
Panel[DynamicModule[{dragstart = {0, 0}, dragval = {0, 0}, box = False, getImage = True,
```





Mathematica
File
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Insert
Format
Cell
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Evaluation
Palettes
Window
Help
Remote Kernels.nb

```
In[9]:= ParallelTable[i, {i, 10}]
```

ParallelTable::nopar : No parallel kernels available; proceeding with sequential evaluation. >

```
Out[9]:= {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
```

Assuming a vector | Use as a *permutation* instead

total | plot points | histogram | mean | more...

SystemInformation[]

Parallel Kernel Status

0 kernels running, idle

ID	Name	Host	Process	CPU	RAM	max RAM	Cores	Version	Close	Busy	Time	Elapsed: 0.000s, speedup: n/a
0	master	Redshift	62130	18.792	52M	89M	8	9.0			0.000	

Launch All
Select Columns...
Kernel Configuration...

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Running...Remote Kernels.nb (compute)

```
(compute) In[1]:=
ParallelTable[i, {i, 10}]

(compute) Out[1]:=
{1, 2, 3, 4, 5, 6, 7, 8, 9, 10}

(compute) In[3]:=
SystemInformation[]

(compute) Out[2]:=
```

Kernel Front End Links Parallel Devices Network

- Streams
- MathLink
- Java
- CUDA
- OpenCL
 - OpenCLLink not loaded Load
- Database
- WebServices

Copy

80x24

- CurrentImage.nb
- Gamma Matrices.nb
- Heat Equation.nb
- Lists.nb
- Mandelbrot.nb
- Remote Kernels.nb
- Watchdog.nb
- ps11.nb
- ps12.nb

200%

Itinerary Jona...ocx

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datura.out

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Delta Boo...pdf

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- .DS_Store
- [Galaxy] Res...gies
- [Solar] Home
- 407 ETR - Pay...pdf
- 1412
- AB.rtf
- AbelianHig gsM...Ln
- Avery Bro...pdf
- BBH.rtf
- benchmark king...0.rtf
- better-disc...n.nb
- Bety's trav...s.txt