Title: 13/14 PSI - Computational Methods in Physics - Lecture 1

Date: Sep 03, 2013 09:00 AM

URL: http://pirsa.org/13090052

Abstract:

Introduction to Mathematica

Erik Schnetter

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Untitled-2

$\sqrt{2}$

In[6]:=

```
x^2 + x - 1
```

Out[6]=

$-1 + x + x^2$

In[7]:=

```
(x + 1) (x - 1)
```

Out[7]=

$(-1 + x)\ (1 + x)$

In[8]:=

```
Simplify[(x + 1) (x - 1)]
```

Out[8]=

$-1 + x^2$

```
Sqrt
```

Sqrt

SqrtBox

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Untitled-2

```
x - 3
```

Out[13]=

```
9
```

In[14]:=

```
x =.
```

In[15]:=

```
x
```

Out[15]=

```
x
```

In[16]:=

```
? Sqrt
```

Sqrt[z] or $\sqrt{z}$ gives the square root of z. >>

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Untitled-2

```
x
```

In[16]:=

```
? Sqrt
```

Sqrt[z] or $\sqrt{z}$ gives the square root of z. >>

In[18]:=

```
Prime[1000]
```

Out[18]=

```
7919
```

In[19]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[19]=

```
{{x → -i}, {x → i}}
```

In[20]:=

```
Limit[1 / n, n → Infinity]
```

Out[20]=

```
0
```

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

Out[18]=

```
7919
```

In[19]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[19]=

```
{{x → -i}, {x → i}}
```

In[20]:=

```
Limit[1 / n, n → Infinity]
```

Out[20]=

```
0
```

Functions

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Untitled-2

```
7919
```

In[19]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[19]=

```
{{x → -i}, {x → i}}
```

In[20]:=

```
Limit[1 / n, n → Infinity]
```

Out[20]=

```
0
```

Functions

In[21]:=

```
f[x_] = Sin[x]
```

Out[21]=

```
Sin[x]
```

Assuming a math expression | Use as *a definition* instead

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

```
7919
```

In[19]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[19]=

```
{{x → -i}, {x → i}}
```

In[20]:=

```
Limit[1 / n, n → Infinity]
```

Out[20]=

```
0
```

Functions

In[21]:=

```
f[x_] = Sin[x]
```

Out[21]=

```
Sin[x]
```

Assuming a math expression | Use as *a definition* instead

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

In[26]:=

```
f[x_] = x + a
```

Out[26]=

```
1 + x
```

In[27]:=

```
f[5]
```

Out[27]=

```
6
```

In[28]:=

```
a =.
```

In[29]:=

```
a
```

Out[29]=

```
a
```

```
f[5]
```

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Untitled-2

```
In[30]:=
f[5]

Out[30]=
6

In[31]:=
g[x_] := x + a

In[32]:=
g[x]

Out[32]=
a + x

In[33]:=
a = 1

Out[33]=
1

In[34]:=
g[x]

Out[34]=
1 + x
```

plot x derivative x integral zeros more...

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Untitled-2

```
5 + a
```

In[38]:=

```
1 &
```

Out[38]=

```
1 &
```

In[39]:=

```
1 &[4]
```

Out[39]=

```
1
```

In[40]:=

```
(2 #) &
```

Out[40]=

```
2 #1 &
```

In[41]:=

```
(2 # &)[5]
```

Out[41]=

```
10
```

prime factorization | divisors | binary form | number of primes ≤ 10 | more...

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Untitled-2

In[42]:=

```
(#1 + #2) &
```

Out[42]=

```
#1 + #2 &
```

In[43]:=

```
(#1 + #2) &[2, 3]
```

Out[43]=

```
5
```

In[44]:=

```
f1[x_, y_] := x + y
```

In[45]:=

```
f1[2, 3]
```

Out[45]=

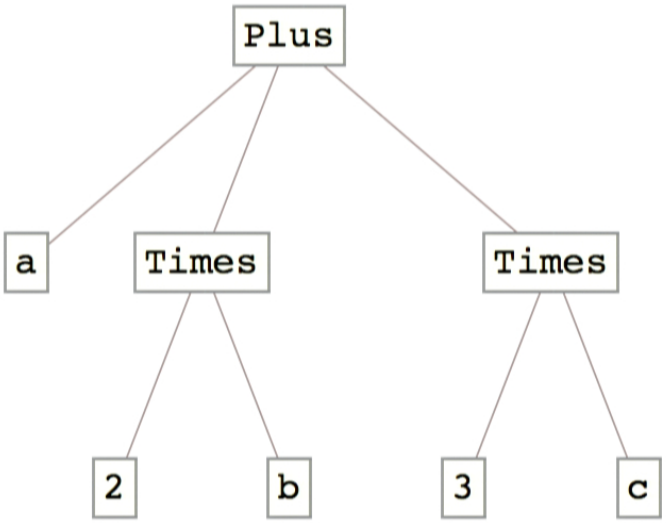
```
5
```

```
f2 := (#1 + #2) &
```

Internal Representation

In[50]:= `a + 2 b + 3 c // TreeForm`

Out[50]//TreeForm=



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Untitled-2

```
In[54]:= {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
Out[54]=
         {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}

In[59]:= Table[i, {i, 1 / 2, 10, 3}]
Out[59]=
```

$$\left\{\frac{1}{2}, \frac{7}{2}, \frac{13}{2}, \frac{19}{2}\right\}$$

```
In[61]:= Sin /@ {0, 1, 2, 3}
Out[61]=
         {0, Sin[1], Sin[2], Sin[3]}

In[62]:= Sin[{1, 2, 3}]
Out[62]=
         {Sin[1], Sin[2], Sin[3]}

In[63]:= f =.

In[64]:= f[{1, 2, 3}]
Out[64]=
         {2, 3, 4}

In[66]:= ClearAll[f]
```

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Untitled-2

```
In[63]:= f =.

In[64]:= f[{1, 2, 3}]
Out[64]=
         {2, 3, 4}

In[66]:= ClearAll[f]

In[67]:= f[{1, 2, 3}]
Out[67]=
         f[{1, 2, 3}]

In[68]:= f /@ {1, 2, 3}
Out[68]=
         {f[1], f[2], f[3]}

In[69]:= (f[#, 2] &) /@ {1, 2, 3}
Out[69]=
         {f[1, 2], f[2, 2], f[3, 2]}

In[70]:= ? /@
```

Map[*f*, *expr*] or *f* /@ *expr* applies *f* to each element on the first level in *expr*.
Map[*f*, *expr*, *levelspec*] applies *f* to parts of *expr* specified by *levelspec*. ≫

```
In[71]:= f@{1, 2, 3}
Out[71]=
         f[{1, 2, 3}]
```

first append delete first change head... more...

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Untitled-2

Differential Equations

```
In[72]:= D[Sin[x], x]
Out[72]=
         Cos[x]

In[73]:= D[Sin[x], x, x, x, x]
Out[73]=
         Sin[x]

In[74]:= Integrate[Sin[x], x]
Out[74]=
         -Cos[x]

         Integrate[Sin[x], {x, 0, 2 Pi}
```

Piecewise
Pi
PieChart
PillaiTrace
PillaiTraceTest

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Untitled-2

```
In[72]:= D[Sin[x], x]
Out[72]=
         Cos[x]

In[73]:= D[Sin[x], x, x, x, x]
Out[73]=
         Sin[x]

In[74]:= Integrate[Sin[x], x]
Out[74]=
         -Cos[x]

In[75]:= Integrate[Sin[x], {x, 0, 2 Pi}]
Out[75]=
         0

In[76]:= Pi
Out[76]=
         π

In[77]:= N[Pi]
Out[77]=
         3.14159

In[78]:= Pi // N
Out[78]=
         3.14159
```

increase precision | integer part | digits | root approximant | more...

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Untitled-2

```
In[72]:= D[Sin[x], x]
Out[72]=
         Cos[x]

In[73]:= D[Sin[x], x, x, x, x]
Out[73]=
         Sin[x]

In[74]:= Integrate[Sin[x], x]
Out[74]=
         -Cos[x]

In[75]:= Integrate[Sin[x], {x, 0, 2 Pi}]
Out[75]=
         0

In[76]:= Pi
Out[76]=
         π

In[77]:= N[Pi]
Out[77]=
         3.14159

In[78]:= Pi // N
Out[78]=
         3.14159
```

increase precision | integer part | digits | root approximant | more...

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75%
100%
125%
150%
200%
300%

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Untitled-2

```
0348610454326648213393607260249141273724587006606315588174881520 92
0962829254091715364367892590360011330530548820466521384146951941 51
1609433057270365759591953092186117381932611793105118548074462379 96
2749567351885752724891227938183011949129833673362440656643086021 39
4946395224737190702179860943702770539217176293176752384674818467 66
9405132000568127145263560827785771342757789609173637178721468440 90
1224953430146549585371050792279689258923542019956112129021960864 03
4418159813629774771309960518707211349999998372978049951059731732 81
6096318595024459455346908302642522308253344685035261931188171010 00
3137838752886587533208381420617177669147303598253490428755468731 15
9562863882353787593751957781857780532171226806613001927876611195 90
9216420199
```

increase precision integer part digits root approximant more...

300%

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Untitled-2

3.14159

In[78]:=

```
Pi // N
```

Out[78]=

```
3.14159
```

In[80]:=

```
N[Pi, 1000]
```

Out[80]=

```
3.14159265358979323846264338327950288419716939937510582097494459230
 78164062862089986280348253421170679821480865132823066470938446095 5
 05822317253594081284811174502841027019385211055596446229489549303 8
 19644288109756659334461284756482337867831652712019091456485669234 6
 03486104543266482133936072602491412737245870066063155881748815209 2
 09628292540917153643678925903600113305305488204665213841469519415 1
 60943305727036575959195309218611738193261179310511854807446237996
 27495673518857527248912279381830119491298336733624406566430860213 9
 49463952247371907021798609437027705392171762931767523846748184676 6
 94051320005681271452635608277857713427577896091736371787214684409 0
 12249534301465495853710507922796892589235420199561121290219608640 3
 44181598136297747713099605187072113499999983729780499510597317328 1
```

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Untitled-2

```
0582231725359408128481117450284102701938521105559644622948954930 38
1964428810975665933446128475648233786783165271201909145648566923 46
0348610454326648213393607260249141273724587006606315588174881520 92
0962829254091715364367892590360011330530548820466521384146951941 51
1609433057270365759591953092186117381932611793105118548074462379 96
2749567351885752724891227938183011949129833673362440656643086021 39
4946395224737190702179860943702770539217176293176752384674818467 66
9405132000568127145263560827785771342757789609173637178721468440 90
1224953430146549585371050792279689258923542019956112129021960864 03
4418159813629774771309960518707211349999998372978049951059731732 81
6096318595024459455346908302642522308253344685035261931188171010 00
3137838752886587533208381420617177669147303598253490428755468731 15
9562863882353787593751957781857780532171226806613001927876611195 90
9216420199
```

In[81]:=

```
Integrate[x^2, x]
```

Out[81]=

$$\frac{x^3}{3}$$

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Untitled-2

```
0582231725359408128481117450284102701938521105559644622948954930 38
1964428810975665933446128475648233786783165271201909145648566923 46
0348610454326648213393607260249141273724587006606315588174881520 92
0962829254091715364367892590360011330530548820466521384146951941 51
1609433057270365759591953092186117381932611793105118548074462379 96
2749567351885752724891227938183011949129833673362440656643086021 39
4946395224737190702179860943702770539217176293176752384674818467 66
9405132000568127145263560827785771342757789609173637178721468440 90
1224953430146549585371050792279689258923542019956112129021960864 03
4418159813629774771309960518707211349999998372978049951059731732 81
6096318595024459455346908302642522308253344685035261931188171010 00
3137838752886587533208381420617177669147303598253490428755468731 15
9562863882353787593751957781857780532171226806613001927876611195 90
9216420199
```

In[82]:=

$$\int x^2 \, dx$$

Out[82]=

$$\frac{x^3}{3}$$

plot x derivative x integral inverse function more...

300%

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Untitled-2

```
2749567351885752724891227938183011949129833673362440656643086021 39
4946395224737190702179860943702770539217176293176752384674818467 66
9405132000568127145263560827785771342757789609173637178721468440 90
1224953430146549585371050792279689258923542019956112129021960864 03
4418159813629774771309960518707211349999998372978049951059731732 81
6096318595024459455346908302642522308253344685035261931188171010 00
3137838752886587533208381420617177669147303598253490428755468731 15
9562863882353787593751957781857780532171226806613001927876611195 90
9216420199
```

In[82]:=

$$\int x^2 \, dx$$

Out[82]=

$$\frac{x^3}{3}$$

plot x derivative x integral inverse function more...

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

```
2749567351885752724891227938183011949129833673362440656643086021 39
4946395224737190702179860943702770539217176293176752384674818467 66
9405132000568127145263560827785771342757789609173637178721468440 90
1224953430146549585371050792279689258923542019956112129021960864 03
4418159813629774771309960518707211349999998372978049951059731732 81
6096318595024459455346908302642522308253344685035261931188171010 00
3137838752886587533208381420617177669147303598253490428755468731 15
9562863882353787593751957781857780532171226806613001927876611195 90
9216420199
```

In[83]:=

$$\int_0^1 x^2 \, dx$$

Out[83]=

$$\frac{1}{3}$$

numerical value | integer part | denominator | numerator | more...

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

$$\int_0^{-} x^2 \, dx$$

Out[83]=

$$\frac{1}{3}$$

In[85]:=

$$\int_{-1}^{+1} \text{Cos}[x] \, dx$$

Out[85]=

2 Sin[1]

In[86]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[86]=

{{x → -i}, {x → i}}

```
DSolve[f'[x] == x, f[x], x]
```

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Untitled-2

$$\int_{-1}^{+1} \text{Cos}[x]\, dx$$

Out[85]=

$$2\,\text{Sin}[1]$$

In[86]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[86]=

$$\{\{x \to -i\}, \{x \to i\}\}$$

In[87]:=

```
DSolve[f'[x] == x, f[x], x]
```

Out[87]=

$$\left\{\left\{f[x] \to \frac{x^2}{2} + C[1]\right\}\right\}$$

In[88]:=

```
DSolve[f'[x] == x, f, x]
```

Out[88]=

$$\left\{\left\{f \to \text{Function}\left[\{x\}, \frac{x^2}{2} + C[1]\right]\right\}\right\}$$

Assuming a list of rules | Use as a two-dimensional array instead

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Untitled-2

In[86]:=

```
Solve[x^2 + 1 == 0, x]
```

Out[86]=

$$\{\{x \to -i\}, \{x \to i\}\}$$

In[87]:=

```
DSolve[f'[x] == x, f[x], x]
```

Out[87]=

$$\left\{\left\{f[x] \to \frac{x^2}{2} + C[1]\right\}\right\}$$

In[88]:=

```
DSolve[f'[x] == x, f, x]
```

Out[88]=

$$\left\{\left\{f \to \text{Function}\left[\{x\}, \frac{x^2}{2} + C[1]\right]\right\}\right\}$$

In[89]:=

```
(x + 1) (x - 1) // Simplify
```

Out[89]=

$$-1 + x^2$$

plot factor x derivative x integral more...

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Untitled-2

```
Collect[(x + y) (x + y) + x^3 + y^2, x]
```

In[98]:=

$$x^2 + x^3 + 2\,x\,y + 2\,y^2$$

Out[98]=

$$x^2 + x^3 + 2\,x\,y + 2\,y^2$$

In[96]:=

```
? Collect
```

Collect[*expr*, *x*] collects together terms involving the same powers of objects matching *x*.
Collect[*expr*, {x_1, x_2, …}] collects together
terms that involve the same powers of objects matching x_1, x_2, ….
Collect[*expr*, *var*, *h*] applies *h* to the expression that forms the
coefficient of each term obtained. ≫

In[99]:=

```
? Expand
```

Expand[*expr*] expands out products and positive integer powers in *expr*.
Expand[*expr*, *patt*] leaves unexpanded any parts of *expr* that are free of the pattern *patt*. ≫

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Untitled-2

Expand[*expr*] expands out products and positive integer powers in *expr*.
Expand[*expr*, *patt*] leaves unexpanded any parts of *expr* that are free of the pattern *patt*. ≫

In[100]:=

```
? Factor
```

Factor[*poly*] factors a polynomial over the integers.
Factor[*poly*, Modulus –> *p*] factors a polynomial modulo a prime *p*.
Factor[*poly*, Extension –> {a_1, a_2, …}] factors a polynomial allowing coefficients that are rational combinations of the algebraic numbers a_i. ≫

In[103]:=

```
Factor[1 + x^2]
```

Out[103]=

$1 + x^2$

```
? Fac
```

Factor
FactorInteger
FactorTerm
FactorTrig
FactorList

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Untitled-2

In[100]:=

```
? Factor
```

Factor[*poly*] factors a polynomial over the integers.
Factor[*poly*, Modulus –> *p*] factors a polynomial modulo a prime *p*.
Factor[*poly*, Extension –> {a_1, a_2, …}] factors a polynomial allowing coefficients that are rational combinations of the algebraic numbers a_i. »

In[107]:=

```
Factor[1 + x^2, Extension → I]
```

Out[107]=

$(-i + x)\ (i + x)$

simplify expand x derivative x integral more...

In[104]:=

```
? Factor
```

Factor[*poly*] factors a polynomial over the integers.
Factor[*poly*, Modulus –> *p*] factors a polynomial modulo a prime *p*.
Factor[*poly*, Extension –> {a_1, a_2, …}] factors a polynomial allowing coefficients that are rational combinations of the algebraic numbers a_i. »

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Untitled-2

In[104]:=

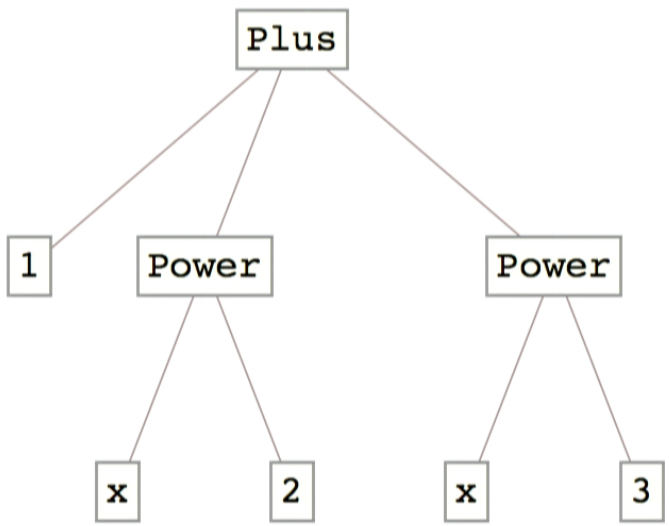
```
? Factor
```

Factor[*poly*] factors a polynomial over the integers.
Factor[*poly*, Modulus -> *p*] factors a polynomial modulo a prime *p*.
Factor[*poly*, Extension -> {a_1, a_2, ...}] factors a polynomial allowing coefficients that are rational combinations of the algebraic numbers a_i. >>

In[108]:=

```
x^3 + x^2 + 1 // TreeForm
```

Out[108]//TreeForm=



plot x derivative x integral zeros more...

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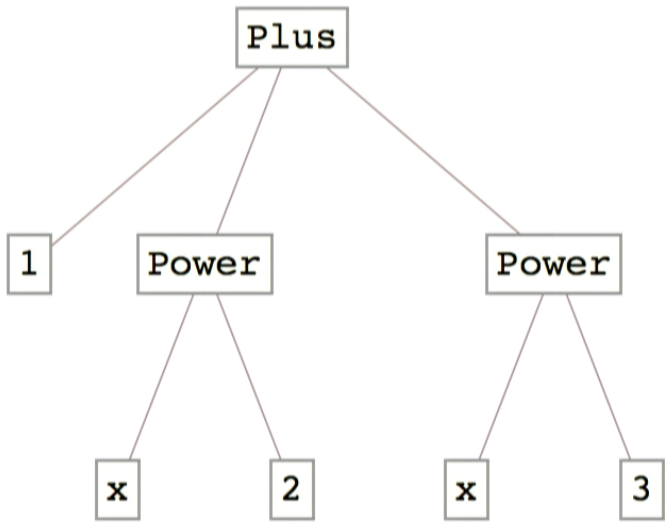
Untitled-2

Factor[*poly*] factors a polynomial over the integers.
Factor[*poly*, Modulus -> *p*] factors a polynomial modulo a prime *p*.
Factor[*poly*, Extension -> {a_1, a_2, ...}] factors a polynomial allowing coefficients that are rational combinations of the algebraic numbers a_i. ≫

In[108]:=

```
x^3 + x^2 + 1 // TreeForm
```

Out[108]//TreeForm=



In[109]:=

```
l = {1, 2, 3}
```

Out[109]=

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

Assuming a vector | Use as a list of digits instead

total mean max reverse more...

200%

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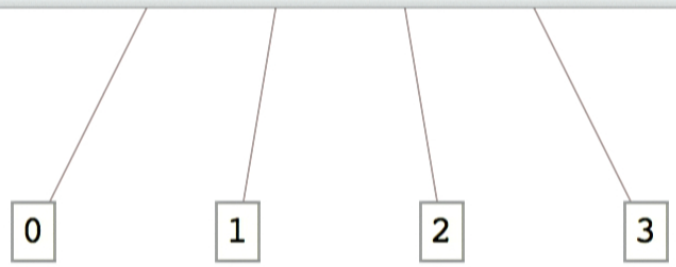
Untitled-2

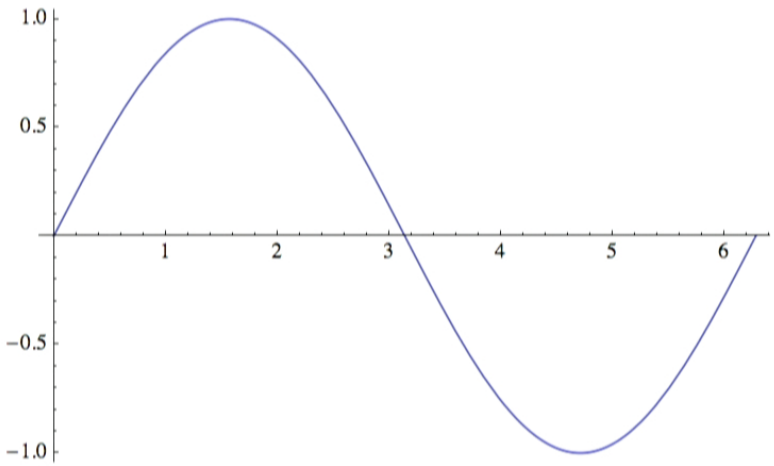


Plots

In[116]:=

```
Plot[Sin[x], {x, 0, 2 Pi}]
```

Out[116]=



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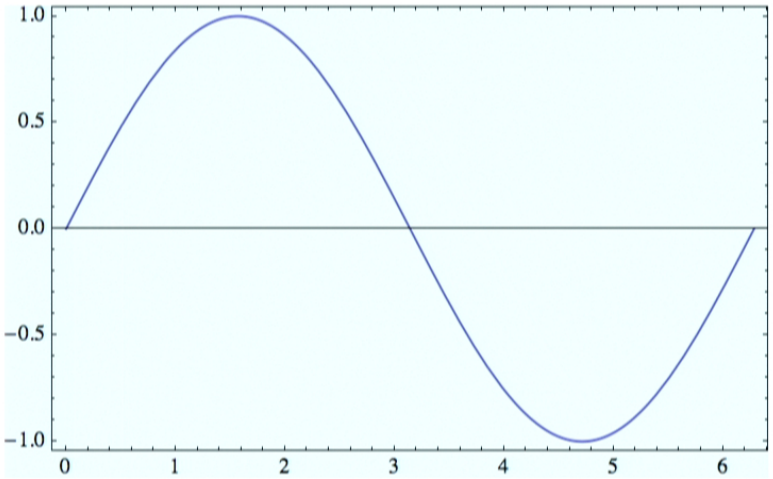
Untitled-2

In[118]:=

```
Show[%117, Background → RGBColor[0.84, 0.92, 1.]]
```

Out[118]=



In[119]:=

```
? Plot
```

Plot[f, {x, x_{min}, x_{max}}] generates a plot of f as a function of x from x_{min} to x_{max}.
Plot[{f_1, f_2, …}, {x, x_{min}, x_{max}}] plots several functions f_i. »

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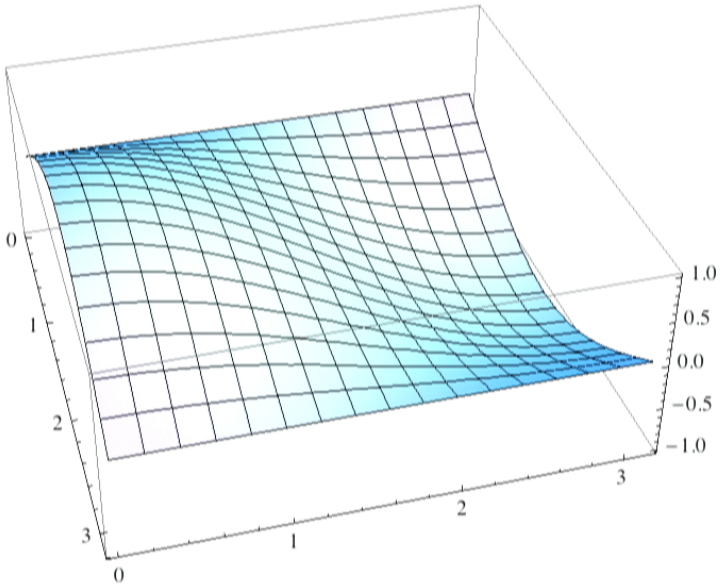
Untitled-2

In[122]:=

```
Plot3D[Sin[x] Cos[y], {x, 0, Pi}, {y, 0, Pi}]
```

Out[122]=



In[123]:=

```
Primes[10]
```

Out[123]=

```
Primes[10]
```

```
Table[Primes[i], {i,
```

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Untitled-2

In[125]:=

```
Prime[10]
```

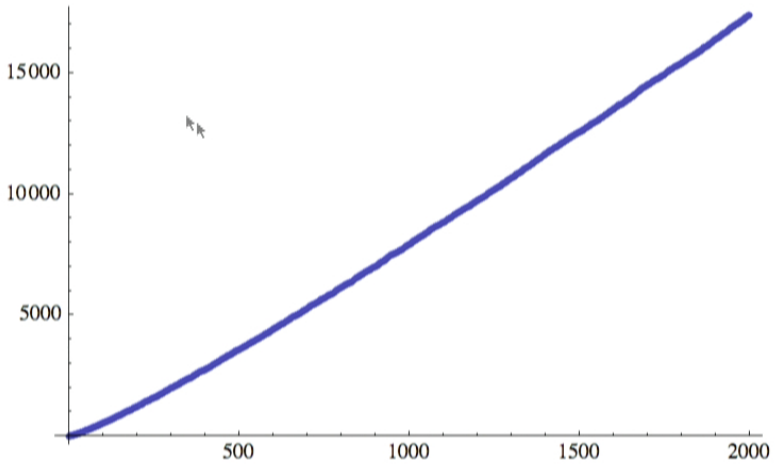
Out[125]=

```
29
```

In[129]:=

```
ListPlot[Table[Prime[i], {i, 1, 2000}]]
```

Out[129]=



frame axes image size plot style... more...

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Untitled-2

In[134]:=

```
fib[10]
```

Out[134]=

```
55
```

In[135]:=

```
fib[20]
```

Out[135]=

```
6765
```

In[136]:=

```
fib[30]
```

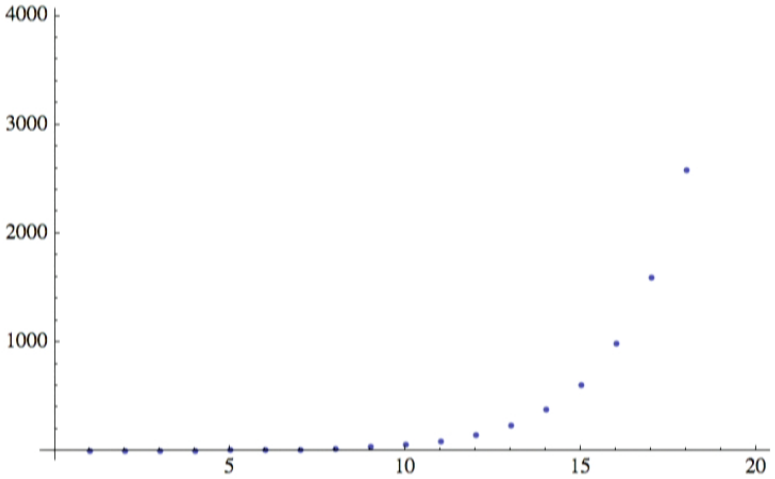
Out[136]=

```
832 040
```

In[138]:=

```
ListPlot[Table[fib[i], {i, 20}]]
```

Out[138]=



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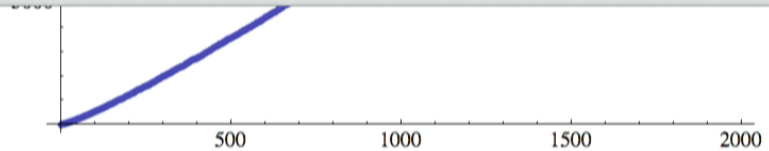
Untitled-2



In[130]:=

```
fib[0] = 0
```

Out[130]=

```
0
```

In[131]:=

```
fib[1] = 1
```

Out[131]=

```
1
```

In[140]:=

```
fib[n_] := fib[n] = fib[n - 1] + fib[n - 2]
```

In[141]:=

```
fib[10]
```

Out[141]=

```
55
```

In[142]:=

```
fib[20]
```

Out[142]=

```
6765
```

In[145]:=

```
fib[300]
```

Out[145]=

```
222 232 244 629 420 445 529 739 893 461 909 967 206 666 939 096 499 764 990 979 600
```

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Untitled-2

```
fib[300]
```

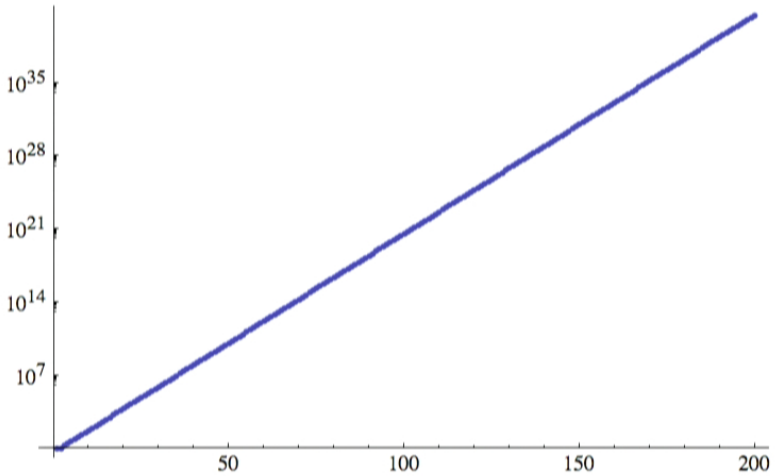
Out[145]=

222 232 244 629 420 445 529 739 893 461 909 967 206 666 939 096 499 764 990 979 600

In[146]:=

```
ListLogPlot[Table[fib[i], {i, 200}]]
```

Out[146]=



In[147]:=

```
Timing[fib[400]]
```

Out[147]=

{0.000525, 176 023 680 645 013 966 468 226 945 392 411 250 770 384 383 304 492 191 886 725 992 896 575 345 044 216 019 675}

absolute timing extract time extract result clear cache first more...

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

```
fib[300]
```

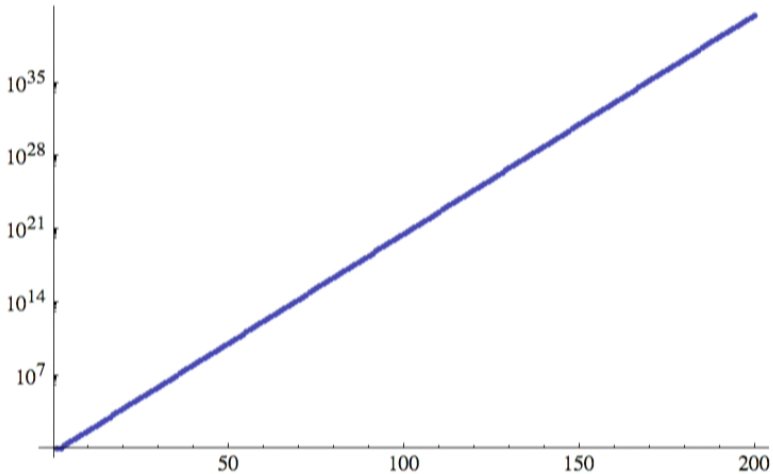
Out[145]=

222 232 244 629 420 445 529 739 893 461 909 967 206 666 939 096 499 764 990 979 600

In[146]:=

```
ListLogPlot[Table[fib[i], {i, 200}]]
```

Out[146]=



In[147]:=

```
Timing[fib[400]]
```

Out[147]=

{0.000525, 176 023 680 645 013 966 468 226 945 392 411 250 770 384 383 304 492 191 886 725 992 896 575 345 044 216 019 675}

In[148]:=

```
Timing[fib[400]]
```

Out[148]=

{$7. \times 10^{-6}$, 176 023 680 645 013 966 468 226 945 392 411 250 770 384 383 304 492 191 886 725 992 896 575 345 044 216 019 675}

absolute timing extract time extract result clear cache first more...

Mathematica File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Untitled-2

50 100 150 200

In[147]:=

```
Timing[fib[400]]
```

Out[147]=

{0.000525, 176 023 680 645 013 966 468 226 945 392 411 250 770 384 383 304 492 191 886 725 992 896 575 345 044 216 019 675}

In[148]:=

```
Timing[fib[400]]
```

Out[148]=

$\{7. \times 10^{-6}, 176\,023\,680\,645\,013\,966\,468\,226\,945\,392\,411\,250\,770\,384\,383\,304\,492\,191\,886\,725\,992\,896\,575\,345\,044\,216\,019\,675\}$

Modules

```
ff[x_, y_] := Module[{a, b}
```

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Untitled-2

$\frac{3}{4}$

In[152]:=

```
a
```

Out[152]=

```
a
```

Low-level Programming

In[153]:=

```
Table[i, {i, 10}]
```

Out[153]=

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

In[154]:=

```
Do[Print[i], {i, 10}]
```

```
1
2
3
4
5
6
7
8
9
10
```

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Untitled-2

In[155]:=

```
numbers = Table[i, {i, 10}]
```

Out[155]=

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

In[156]:=

```
numbers
```

Out[156]=

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

In[157]:=

```
nonumbers = Do[Print[i], {i, 10}]
1
2
3
4
5
6
7
8
9
10
```

In[160]:=

```
nonumbers
```