Review

Integers
Floating Point

Dynamic Typing – no declarations

```
x = 5
y = 6.3
```

Names start with a letter,   cAsE SeNsiTiVe.
Long names OK.

Review Character Strings

Dynamic typing – no declaration
No memory allocation
Immutable

```
s = “Good Afternoon”

len(s)                  # length of string
```

Review String Slicing

```
s = “Good Afternoon”

s[0]  evaluates to “G”

s[5:10] selects “After”        # string slicing

s[:10] selects “Good After”
s[5:]  selects “Afternoon”

s[-4:] selects “noon”      # last 4 characters
```

String Methods

String is a Class with data & subroutines:

```
t = s.upper()
pos = s.find(“A”)
```

____

```
first = “George”
last = “Washington”
name = first + “ “ + last
                 # string concatenation
```

Review Lists

Ordered sequence of items

Can be floats, ints, strings, Lists

a = [16, 25.3, “hello”, 45]

a[0] contains 16

a[-1] contains 45

a[0:2] is a list containing [16, 25.3]

Create a List

```
days = [ ]
days.append(“Monday”)
days.append(“Tuesday”)

years = range(2000, 2014)
```

List Methods

List is a Class with data & subroutines:

d.insert( )
d.remove( )
d.sort( )

Can concatenate lists with +

String split

```
s = “Princeton Plasma Physics Lab”

myList = s.split()          # returns a list of strings

print myList
      [ “Princeton”, “Plasma”, “Physics”, “Lab” ]

help(str.split)                  # delimiters, etc.
```

Tuple

Designated by ( ) parenthesis

A List that can not be changed. Immutable.
No append.

Good for returning multiple values from a subroutine function.

Can extract slices.

Review math module

```
import math
dir(math)

math.sqrt(x)
math.sin(x)
math.cos(x)
```

```
from math import *
dir()

sqrt(x)
```

```
from math import pi
dir()

print pi
```

import a module

```
import math                # knows where to find it
________________________________________________
import sys
sys.path.append("/u/efeibush/python")
import  cubic.py           # import your own code
________________________________________________
if task == 3:
    import math            # imports can be anywhere
```

Review Defining a Function

Block of code separate from main.

Define the function before calling it.

```
def myAdd(a, b):        # define before calling
     return a + b

p = 25                  # main section of code
q = 30

r = myAdd(p, q)
```

Keyword Arguments

Provide default values for optional arguments.

```
def setLineAttributes(color=“black”,
    style=“solid”, thickness=1):
    ...
```

```
# Call function from main program
setLineAttributes(style=“dotted”)
setLineAttributes(“red”, thickness=2)
```

Looping with the range() function

```
for i in range(10):        # i gets 0 - 9
```

range() is limited to integers

numpy provides a range of floats

Summary

Integer, Float

String

List

Tuple

def function

Keywords: if elif else

while for in

import print

Indenting counts :

Run python as Interpreter

type()
dir()
help()

numpy module

ndarray ***class***

Items are all the same type.

Contiguous data storage in memory of items.

Considerably faster than lists.

Class with data and methods (subroutines).

numpy module

ndarray ***class***

```
import numpy

dir()
dir(numpy)
help(numpy)
help(numpy.ndarray)      # class
help(numpy.array)        # built-in function
```

numpy module

```
import numpy
dir(numpy)
help(numpy.zeros)                tuple

a = numpy.zeros( (3,5) )
```

# create 3 rows, 5 columns

```
[   [ 0., 0., 0., 0., 0. ],
    [ 0., 0., 0., 0., 0. ],
    [ 0., 0., 0., 0., 0. ] ]
```

# default type is float64

numpy Array Access

Access order corresponding to printed order:

[row] [column] index starts with 0

a[0][2] = 5

```
[      [ 0.,  0.,  5.,  0.,  0. ],
       [ 0.,  0.,  0.,  0.,  0. ],
       [ 0.,  0.,  0.,  0.,  0. ]  ]
```

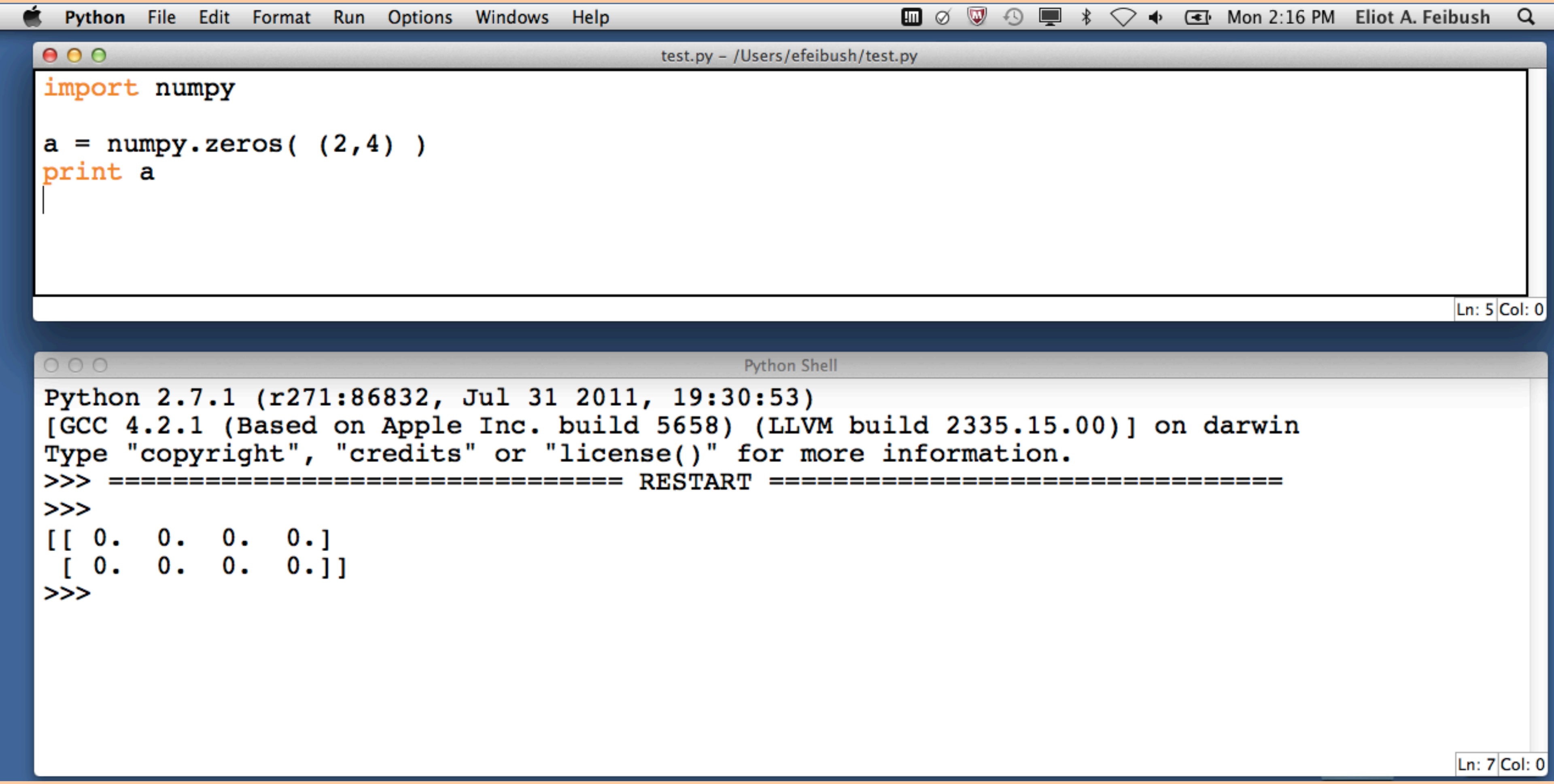
idle

Integrated Development Environment (IDE)

- Color-coded syntax
- statement completion
- debugger

Written in Python using tkinter GUI module

idle IDE


Python File Edit Format Run Options Windows Help
Mon 2:16 PM Eliot A. Feibush
test.py - /Users/efeibush/test.py
Ln: 5 Col: 0
Python Shell
Ln: 7 Col: 0

```
import numpy

a = numpy.zeros( (2,4) )
print a
```

```
Python 2.7.1 (r271:86832, Jul 31 2011, 19:30:53)
[GCC 4.2.1 (Based on Apple Inc. build 5658) (LLVM build 2335.15.00)] on darwin
Type "copyright", "credits" or "license()" for more information.
>>> ================================ RESTART ================================
>>>
[[ 0.  0.  0.  0.]
 [ 0.  0.  0.  0.]]
>>>
```

Can save text in interpreter window to a file.

control-p   control-n to recall commands

Programming Exercise Prep

Mac: Editing source code

- Textedit
  - Preferences
    - Format: Plain text
  - Open and Save
    - Uncheck: Add .txt extension

Save: File Format – Plain Text

Programming Exercise Prep

Mac: Run python from command line

Spotlight terminal

```
$ python myprogram.py
```

Array Index Exercise

Write a python program:

- Create an array (6, 3)
- Set each element to rowIndex + columnIndex
- print the array

```
[ [ 0.  1.  2.  ]
  [ 1.  2.  3.  ]
  [  2.  3.  4. ]
  [  3.  4.  5. ]
  [  4.  5.  6. ]
  [  5.  6.  7. ] ]
```

edit index.py

python index.py

1. Create Array

```
a = numpy.linspace(start, stop, nPoints, inclusive)
```

# array of evenly spaced floats

# begins with start

# ends with stop

# can include/exclude stop   True/False

```
     example: 0., 2.5, 101
              0., 2.5, 100, False
```

Useful to make "range" of floats

```
    for i in a:
```

ndarray has __iter__()

Arrays are iterable

1a. Create Array

```
alog = numpy.logspace(start, maxExp, nSteps)
```

Example: 0., 10., 11

2. Create Array

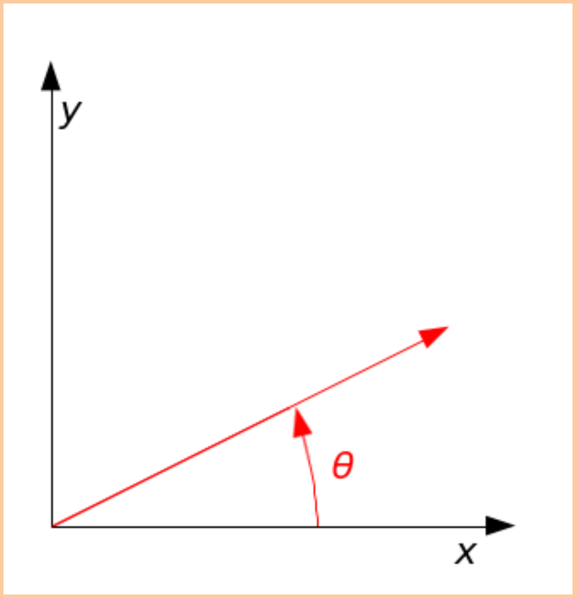
```
b = numpy.array( [ 2., 4., 6. ] )
    # 1-D from list

    # range(start, end, incr) returns a list so
b = numpy.array( range(10) )
     array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])

b = numpy.array( ( 2., 4., 6. ) )
                          # 1-D from tuple
```

Rotation Matrix Exercise

Write a python program:

Create a 2 x 2 rotation matrix, 30 degrees:

```
[   cos(30)        sin(30)
    -sin(30)       cos(30)    ]
```



radians = degrees * pi / 180.

Circle Exercise

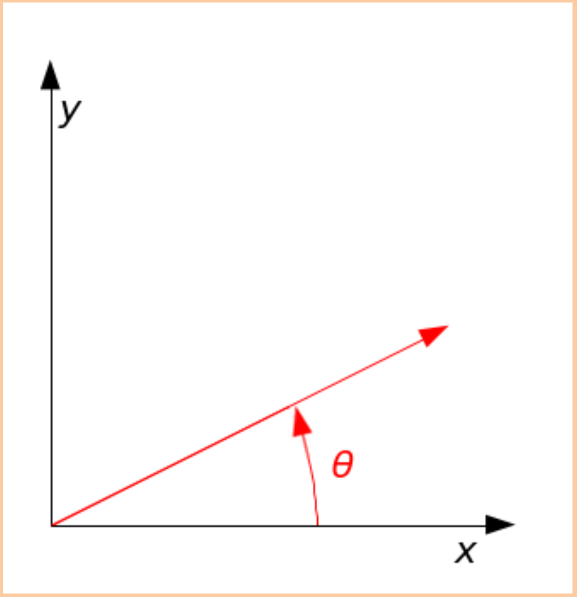
Add to your python program:

Create 18 *xy* points around unit circle

(18, 2) array

x = cosine(angle)

y = sine(angle)



```
print a.round(3)
```

Pointer vs. Deep Copy

```
a = numpy.zeros( (3, 3) )
b = a       # b is a pointer to a
c = a.copy()     # c is a new array

b is a      # True
c is a      # False
```

Views

base

Array Arithmetic

```
a = numpy.array( range(10, 20) )
```

a + 5

a – 3

a * 5

a / 3.14

a.sum()

a > 15

    (a > 15).sum()

Array Arithmetic by Index

```
a = numpy.array( range(10) )
b = numpy.array( range(0, 1000, 100) )

a + b            # a[0] + b[0], a[1] + b[1] ...
a – b
a * b            # not row, column matrix product
a / b
```

The 2 arrays must be the same shape.

Row, Column Matrix Product

```
c = numpy.dot(a, b)
```

Dot product of 2 arrays.
Matrix multiplication for 2D arrays.

Transform Exercise

Add to your python program:

- Transform 18 points by the rotation matrix.
- Save in new array.
- Scale up by factor of 2.

$$\left[\ 18\text{x}2\ \right] \cdot [\,2 \text{ x } 2\,]$$

$$\cancel{[\,2 \text{ x } 2\,] \cdot \left[\ 18\text{x}2\ \right]}$$

Cross Product

```
zA = numpy.cross(xA, yA)
```

Note: we have been using *numpy.* functions

Array Shape

```
a = numpy.linspace(2, 32, 16)

a = a.reshape(4, 4)  # ndarray . method

a.shape          # ndarray attribute     tuple (4, 4)

a = numpy.linspace(2,32,16).reshape(8,2)
```

Array Diagonals

```
a = numpy.linspace(1, 64, 64)

a = a.reshape(8, 8)

numpy.triu(a)          # upper triangle
numpy.tril(a)          # lower triangle

numpy.diag(a)          # main diagonal
numpy.diag(a, 1)       # 1 above
numpy.diag(a, -1)      # 1 below
```

numpy.array Order [row] [column] vs. Internal Storage Order

C is default, Fortran can be specified [contiguous] []

```
c = numpy.zeros( (2,4), dtype=numpy.int8)
f = numpy.zeros( (2,4), dtype=numpy.int8, order=”F”)
                    # show   c.flags   f.flags

c[0][1] = 5       # show   c.data[:]
f[0][1] = 5        # show  f.data[:]
```

numpy.array [][] access is the same regardless of internal storage order

ndarray.flags

<u>Interpreter</u>

Look at array flags

dir(a.flags)

<u>Program</u>

```
    status = a.flags.c_contiguous
    status = a.flags.f_contiguous
```

# boolean True or False

```
ndarray.flatten()
```

# ‘F’ or ‘C’ (default)

Array Data Types

numpy.float64 is the default type

float32

int8, int16, int32, int64, uint8, uint16, uint32, uint64

complex64, complex128

bool   - True or False

a.dtype   shows type of data in array

```
>>> help(numpy.ndarray)
```
Parameters
Attributes

Multi-Dimensional Indexing

```
a = numpy.array( range(12) )
a = a.reshape(2,6)      # 2 rows, 6 columns
```

a[1][5] contains 11

a[1, 5] is equivalent, more efficient

1. Array Slicing

```
a = numpy.array(range(0, 100, 10))
```

Array([0, 10, 20, 30, 40, 50, 60, 70, 80, 90])

a[2:4] contains 20, 30

a[-4 : -1] contains 60, 70, 80

Slicing returns ndarray

2. Array Slicing

```
a = numpy.array(range(64)).reshape(8,8)
```

a[3, 4] contains 28

```
asub = a[3:5,   4:6]
```

Very useful for looking at data & debugging.

```
a[:,2]       # all rows, column 2
a[3, 2:5]    # row 3, columns 2 and 3 and 4
```

Array Stuff

```
a.T
a.min()
a.max()
a.round()
a.var()
a.std()
```

Organize Arrays

Make a list of arrays named a, b, and c:

```
w = [ a, b, c]

len(w)              # length of list is 3

w[1].max()          # use array method
```

numpy Tutorial

wiki.scipy.org/Tentative_Numpy_Tutorial

docs.scipy.org/doc/numpy/reference/routines.html

numpy for Matlab Users
wiki.scipy.org/NumPy_for_Matlab_Users

1. Plotting

matplotlib – designed to look like MATLAB plot

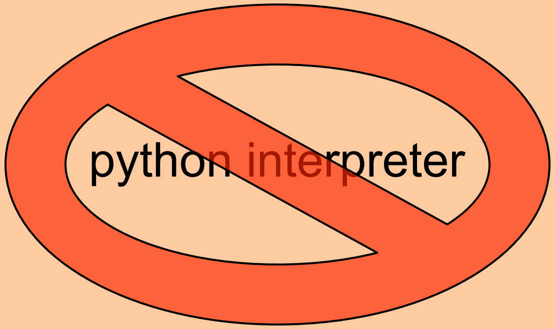
200 subroutines for various plots.

Generally available with Python

matplotlib.org
        gallery

Plotting on nobel.princeton.edu

```
> ipython27 -pylab
```



Bring up plot windows as separate threads, no blocking.
Draw commands are displayed sequentially.

import myplot
reload(myplot)
dir(myplot)

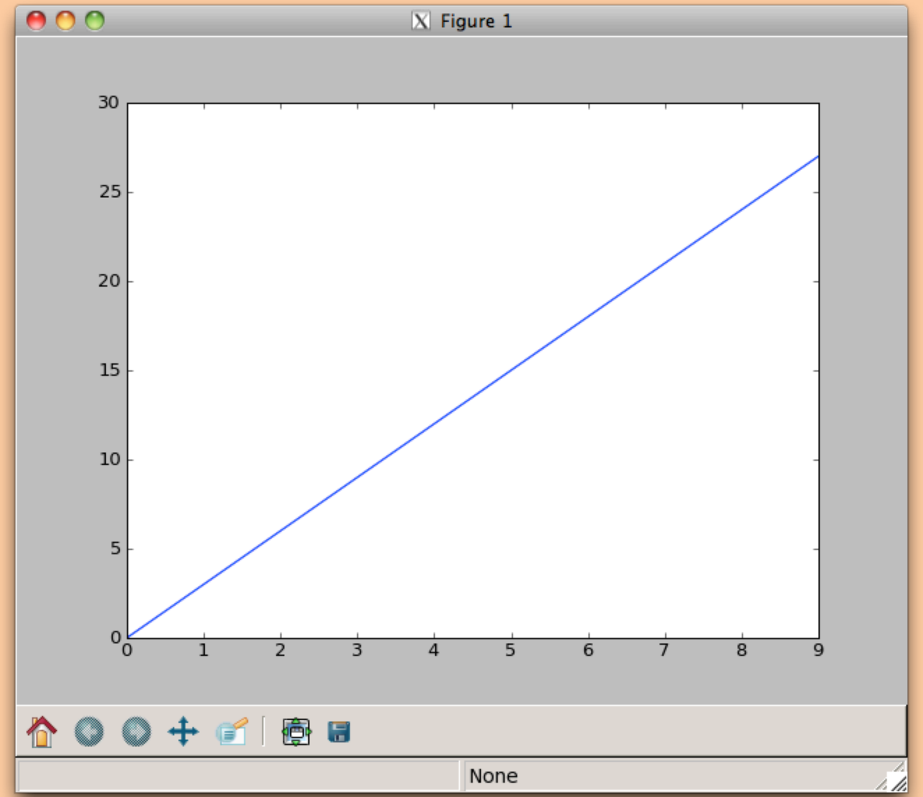
```
ipython27 --pylab --classic --logfile mytype.txt
        dash dash pylab
```

Plot Exercise

New python program:

Create a numpy array of ten ***X*** values.

Create a numpy array of ten ***Y*** values.



```
import matplotlib.pyplot as g
g.plot(x, y)
g.show()
```

Plot Circles Exercise

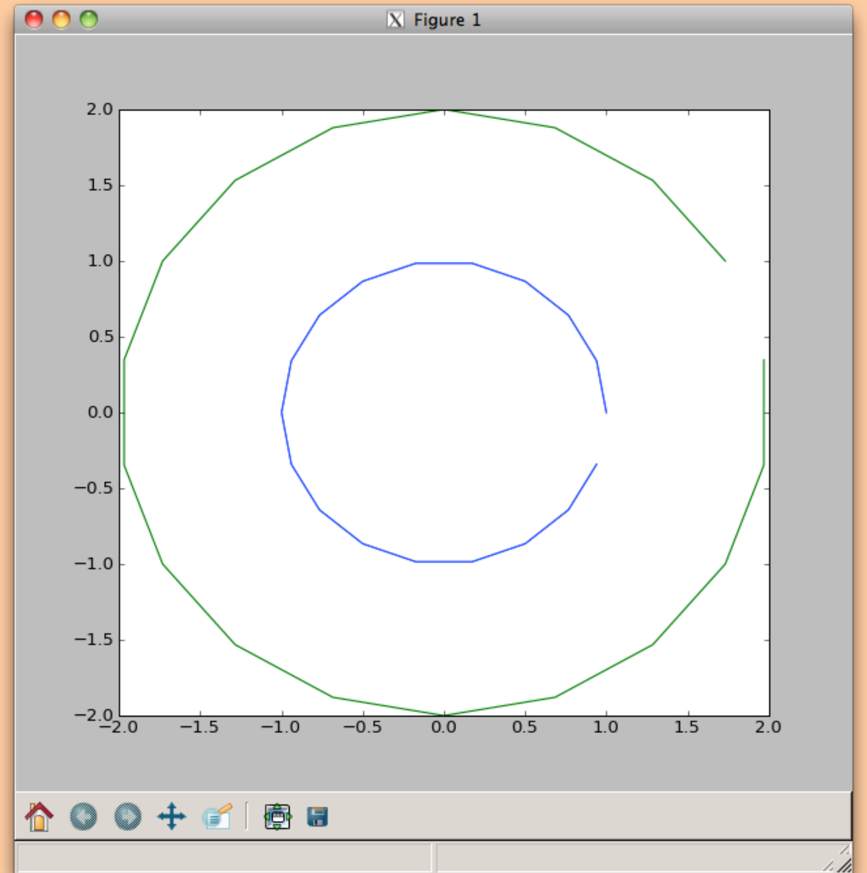
Add to your python program:

Slice both (18, 2) arrays into:

x array

y array

```
g.plot(ax, ay)
g.plot(bx, by)
```



matplotlib Contour Plot

```
r = numpy.random.rand(10,10)

g.contour(r)        # contour line plot

fig2 = g.figure()      # start new window
fig2.canvas.manager.window.Move((648,20))

g.contourf(r)      # filled contour plot
```

matplotlib LaTeX

```
import matplotlib.pyplot as plt

plt.rc(“text”, usetex=True)
plt.xlabel( r”\textbf{Time}” )
```

```
   # plt.xlabel(“Time”)
```

latex.py example

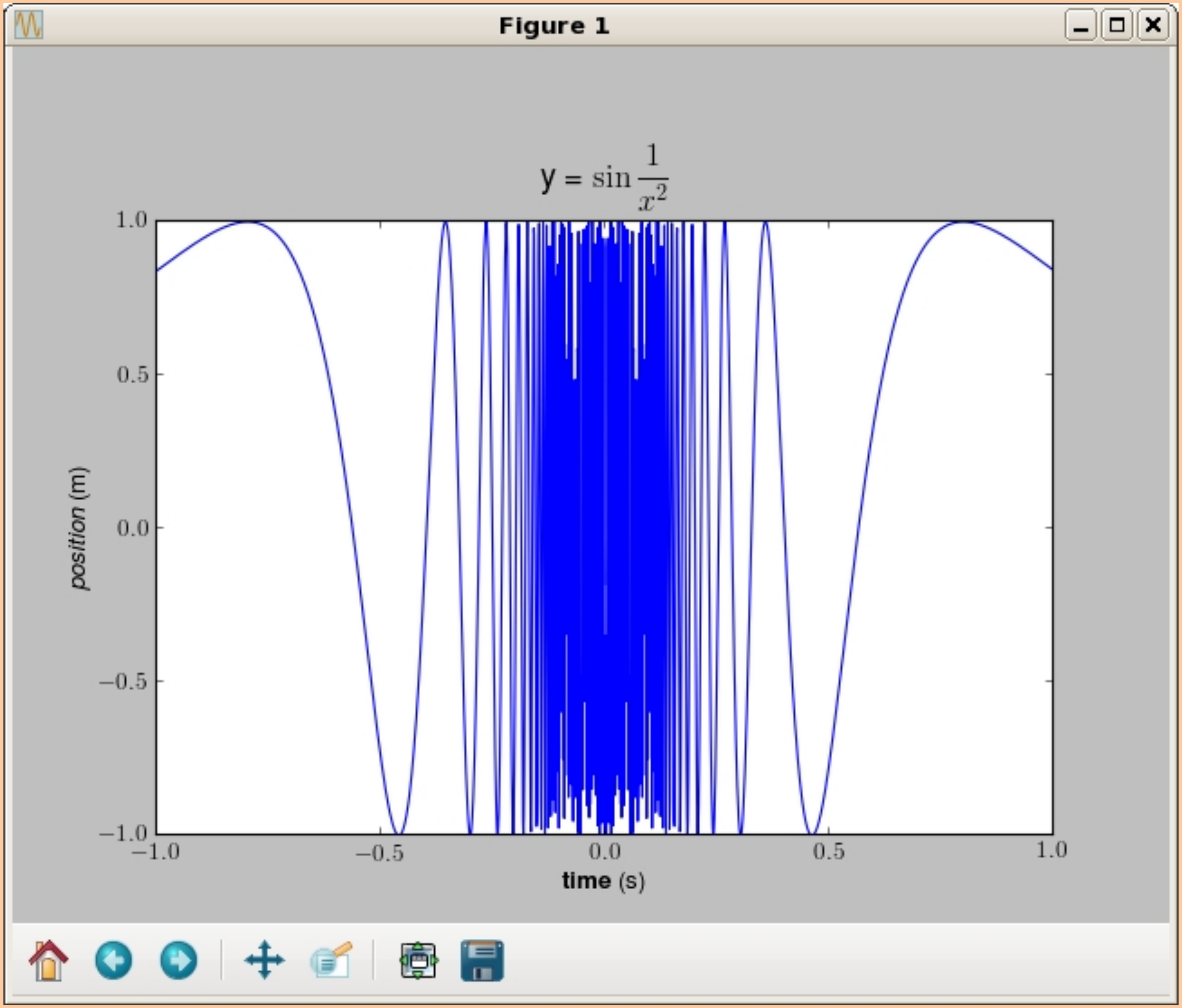


Figure 1
y = $\sin\frac{1}{x^2}$
1.0
0.5
0.0
−0.5
−1.0
position (m)
−1.0
−0.5
0.0
0.5
1.0
time (s)

Python at princeton.edu

```
ssh nobel.princeton.edu
compton%  which python
/usr/bin/python
```

version 2.6.6

```
/usr/bin/python2.7
```

version 2.7.3

```
idle

idle27
```

More Info & Resources

docs.scipy.org

princeton.edu/~efeibush/python/numpy

Princeton University Python Community

princetonpy.com

Where to?

Graphing & visualization

Writing new classes

scipy – algorithms & math tools

Image Processing

Visualization toolkit – python scripting

Eclipse IDE

Multiprocessing

Python → GPU, CUDA

Reading a netCDF File

Popular file format for scientific data

- Multi-dimensional arrays

scipy – netcdf_file class for read/write

numpy – n-dimensional data arrays

Read a Text File

```
gFile = open("myfile.txt”,  “r”)

for j in gFile:     # python magic:  text file iterates on lines
        print j    # print each line

gFile.close()
```

Write a Text File

```
f = open("myfile.txt", "w")
a = 1
b = 2

f.write("Here is line " + str(a) + "\n");
f.write("Next is line " + str(b) + "\n");

f.close()
```

Command Line Arguments

```
import sys
print sys.argv
```

sys.argv is a list
sys.argv[0] has the name of the python file
        Subsequent locations have command line
args

>>> help(sys)

Command Line Scripts

Upgrade to csh or bash shell scripts

    shell agnostic

Much better text handling

Process control - popen()

Shell Scripting

```
#!/bin/csh

foreach file (*.py)
        echo $file
        end
```

```
import os
fileL = []     # set up a list
for f in os.listdir("."):
        if f.endswith(".py"):
                print f
                fileL.append(f)
fileL.sort() # list function, sort in place
print fileL
```

Python + GUI

tkinter

pyqt

wxpython