
PyQ Documentation

Release 4.1.1

Enlightenment Research, LLC.

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PyQ brings the [Python programming language](#) to the [kdb+ database](#). It allows developers to seamlessly integrate Python and q codes in one application. This is achieved by bringing the Python and q interpreters in the same process so that codes written in either of the languages operate on the same data. In PyQ, Python and q objects live in the same memory space and share the same data.

CHAPTER 1

Quick start

Install pyq

Don't have pyq installed? Run

```
$ pip install \
  -i https://pyq.enlnt.com \
  --no-binary pyq pyq
```

First, make sure that PyQ is *installed* and *up-to-date*. Start an interactive session:

```
$ pyq
```

Import the `q` object from `pyq` and the `date` class from the standard library module `datetime`:

```
>>> from pyq import q
>>> from datetime import date
```

Drop to the `q()` prompt and create an empty `trade` table:

```
>>> q()
q)trade: ([]date:();sym:();qty:())
```

Get back to the Python prompt and insert some data into the `trade` table:

```
q)\
>>> q.insert('trade', (date(2006,10,6), 'IBM', 200))
k('0')
>>> q.insert('trade', (date(2006,10,6), 'MSFT', 100))
k('1')
```

(In the following we will skip `q()` and `\` commands that switch between `q` and Python.)

Display the result:

```
>>> q.trade.show()
date      sym  qty
-----
2006.10.06 IBM   200
2006.10.06 MSFT  100
```

Define a function in q:

```
q)f:{[s;d]select from trade where sym=s,date=d}
```

Call the q function from python and pretty-print the result:

```
>>> x = f('IBM', date(2006,10,6))
>>> x.show()
date      sym  qty
-----
2006.10.06 IBM   200
```

For an enhanced interactive shell, use pyq to start IPython:

```
$ pyq -m IPython
```

See the [ipython section](#) for details.

What's New in PyQ 4.1

Release 4.1

Date 2017-08-30

Summary – Release highlights

- Improved calling Python functions from q. - Objects of any type supported by K() can be returned. - Python functions can be called from multiple q threads.
- Calls from Python to q will now release GIL allowing concurrent execution of q code from multiple threads.
- Added a backtrace mode (requires kdb+ 3.5 or later) in which q stack trace is printed on q errors.
- Experimental Windows support.
- Performance improvements.

Return arbitrary objects from Python functions called from q

When a Python function is called from q, the returned Python objects are now automatically converted to q. Any type accepted by the K() constructor can be successfully converted. For example, the `numpy.eye` function returns a 2-D array with ones on the diagonal and zeros elsewhere. It can be called from q as follows:

```
q)p)import numpy
q)p)q.eye = numpy.eye
q)eye 3 4 1
0 1 0 0
0 0 1 0
0 0 0 1
```

Calling Python from peach

Python functions can now be safely called from multiple q threads. For example, the following session illustrates how peach distributes work between four threads:

```
$ q -s 4
q)p)import threading
q)p)q.tid = threading.get_ident
q){group (distinct x)?x} {tid()} peach til 19
0| 0 4 8 12 16
1| 1 5 9 13 17
2| 2 6 10 14 18
3| 3 7 11 15
```

Backtrace mode

Note: Backtrace mode is available when PyQ is running under kdb+ version 3.5 or later.

To activate the backtrace mode, set the environment variable `PYQ_BACKTRACE`.

For example:

```
$ PYQ_BACKTRACE=yes pyq
>>> q('f:{g[]};g:{1+`};f[]')
Traceback (most recent call last):
..
_k.error: ('type', k('(((1+`};2);(..g";";-1;"{1+`}");2;5);(({g[]};2);(..f";";-1;"
↪{g[]}");1;4);..'))
kdb+ backtrace:
[5]  g:{1+`}
      ^
[4]  f:{g[]}
      ^
[3]  f:{g[]};g:{1+`};f[]
      ^
..
```

Experimental Windows support

PyQ can now be installed on Windows. We tested PyQ 4.1.0 with Python 3.6 build using VS 2015 and 2017 and 32-bit kdb+ 3.5.

PyQ 4.1.1 adds support for Python 2.7.x with [Microsoft Visual C++ Compiler for Python 2.7](#).

Latest updates on Windows support, as well as latest patches can be found at [Github](#).

What's New in PyQ 4.0

Release 4.0

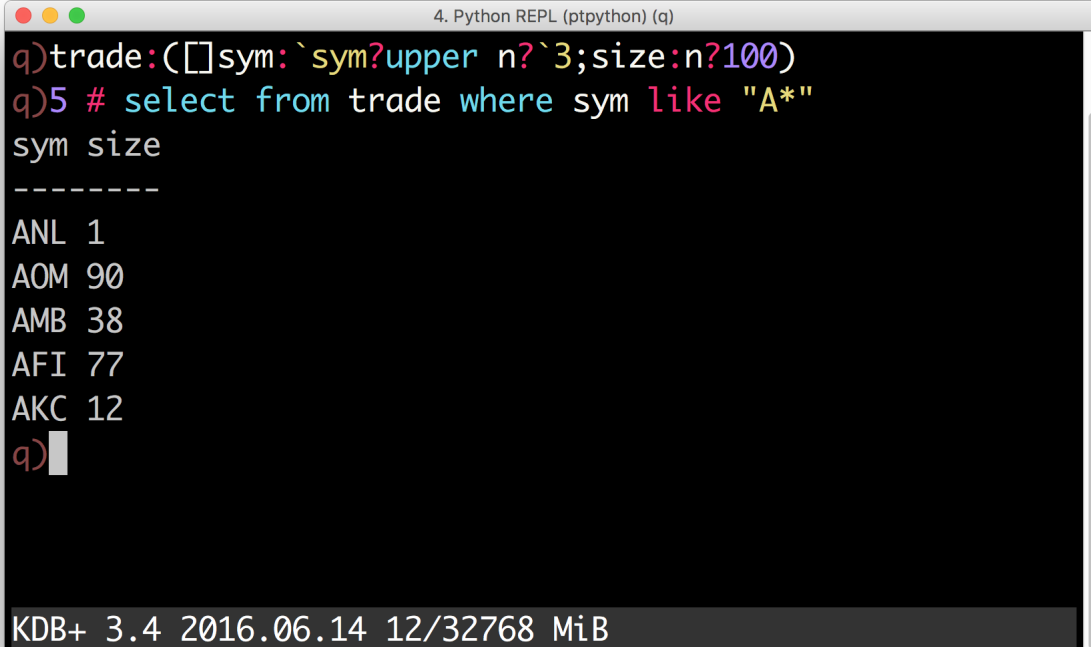
Date 2017-03-02

Summary – Release highlights

- Enhanced q) prompt with syntax highlighting.
- New operators: <<, >> and @.
- Improved means for constructing K objects of arbitrary types.
- Type casts using attribute syntax.
- Improved numpy interoperability.
- Restored support for KDB+ 2.x.
- Better documentation.
- More k.h functions are exposed to Python internally.
- Added convenience scripts for starting different interactive sessions.
- Additional conversions between K and native Python objects.
- Redesigned adverbs

Enhanced q) prompt

The q) prompt will now use the prompt toolkit when available to provide a separate command history, q syntax highlighting and a status bar displaying system information.



```
4. Python REPL (ptpython) (q)
q)trade:([]sym:`sym?upper n?`3;size:n?100)
q)5 # select from trade where sym like "A*"
sym size
-----
ANL 1
AOM 90
AMB 38
AFI 77
AKC 12
q)
KDB+ 3.4 2016.06.14 12/32768 MiB
```

New operators

Three new operators are defined for `K` objects: `<<`, `>>` and `@`.

Shift operators

Shift operators `<<` and `>>` can now be used to shift elements in `K` lists:

```
>>> q.til(10) << 3
k('3 4 5 6 7 8 9 ON ON ON')
>>> q.til(10) >> 3
k('ON ON ON 0 1 2 3 4 5 6')
```

The @ operator

Users of Python 3.5 or later can now use the new binary operator `@` to call `q` functions without using parentheses:

```
>>> q.til @ 5
k('0 1 2 3 4')
```

The same operator between two functions creates a function composition. For example, the dot product can be defined succinctly as

```
>>> dot = q.sum @ q('*')
>>> dot([1, 2, 3], [3, 2, 1])
k('10')
```

Typed constructors and casts

Atoms and lists of like atoms can now be constructed from Python objects using typed constructors. For example, by default, a list of strings passed to the default `K` constructor becomes a symbol list:

```
>>> colors = K(['white', 'blue', 'red'])
>>> colors
k('`white`blue`red')
```

If you want to create a list of strings, you can use a typed constructor:

```
>>> K.string(["Donald E. Knuth", "Edsger W. Dijkstra"])
k('("Donald E. Knuth";"Edsger W. Dijkstra")')
```

If you already have a symbol list and want to convert it to strings, you can use the attribute access notation to perform the cast:

```
>>> colors.string
k('("white";"blue";"red")')
```

Similar operations can be performed with numeric data. For example, to create a matrix of single-precision floats (real), call

```
>>> m = K.real([[1, 0, 0],
...             [0, 1, 0],
...             [0, 0, 1]])
```

```
>>> m
k('(1 0 0e;0 1 0e;0 0 1e)')
```

To cast the result to booleans — access the `boolean` attribute:

```
>>> m.boolean.show()
100b
010b
001b
```

Unlike `q`, Python does not have special syntax for missing values and infinities. Those values can now be created in PyQ by accessing `na` and `inf` attributes on the typed constructors:

```
>>> for x in [K.int, K.float, K.date, K.timespan]:
...     print(x.na, x.inf)
ONi 0Wi
On 0w
ONd 0Wd
ONn 0Wn
```

Interoperability with NumPy

Matrices and arrays of higher dimensions

Arrays with `ndim > 1` can now be passed to `q` and they become nested lists. For example:

```
>>> q.x = numpy.arange(12, dtype=float).reshape((2, 3, 2))
>>> q.x
k('( (0 1f;2 3f;4 5f); (6 7f;8 9f;10 11f) )')
```

Similarly, `ndim > 1` arrays can be constructed from lists of regular shape:

```
>>> numpy.array(q.x)
array([[[ 0.,  1.],
        [ 2.,  3.],
        [ 4.,  5.]],

       [[ 6.,  7.],
        [ 8.,  9.],
        [10., 11.]])
```

Times, dates and timedeltas

Prior to 4.0, conversion of temporal data to NumPy arrays would expose internal integer values. For example, a list of months

```
>>> months = q('2001.01m + til 3')
```

would become an integer array when converted to NumPy:

```
>>> numpy.array(months).tolist()
[12, 13, 14]
```

Now, an array of type `datetime64` is returned:

```
>>> numpy.array(months)
array(['2001-01', '2001-02', '2001-03'], dtype='datetime64[M]')
```

Note that the resulting array has different numeric values and cannot share the data with the K object. To share the data and/or to get an array as in older versions, one should use the new `data` attribute:

```
>>> a = numpy.asarray(months.data)
>>> a.tolist()
[12, 13, 14]
```

An array constructed from the `data` attribute will use the same underlying storage. This means that changing the array will change the K object.

```
>>> a[:] += 998*12
>>> months
k('2999.01 2999.02 2999.03m')
```

Additional conversions

Complex numbers

Complex numbers can now be passed to and obtained from kdb+. When passed to kdb+, complex numbers are automatically converted to dictionaries with keys “re” and “im” and lists of complex numbers are converted to tables with columns “re” and “im”.

```
>>> q.z = [1 + 2j, 3 + 4j, 5 + 6j]
>>> q.z.show()
re im
-----
1  2
3  4
5  6
>>> [complex(x) for x in q.z]
[(1+2j), (3+4j), (5+6j)]
```

Path objects

`Path` objects can now be used where q path handle symbols are expected

```
>>> import pathlib
>>> path = pathlib.Path('xyz')
>>> q.set(path, 42)
k('`xyz')
>>> q.get(path)
k('42')
>>> path.unlink()
```

Named tuples

Named tuples are now converted to dictionaries:

```
>>> from collections import namedtuple
>>> Point = namedtuple('Point', 'x,y')
>>> q.point = Point(1, 2)
>>> q.point
k('`x`y!1 2')
```

As a consequence, a uniform list of named tuples is converted to a table:

```
>>> q.points = [Point(1, 2), Point(3, 4), Point(5, 6)]
>>> q.points.show()
x y
---
1 2
3 4
5 6
```

Redesigned adverbs

Adverbs can now be used on functions with different ranks. For example, `scan` and `over` can be used with monadic functions. To illustrate, the following code generates a Pascal triangle:

```
>>> f = q('{ (0,x)+x,0}')
>>> f.scan(6, 1).show()
1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1
```

If only the last row is of interest – use `over`:

```
>>> f.over(6, 1)
k('1 6 15 20 15 6 1')
```

Installation

PyQ can be installed using the standard Python package management tool - `pip`. See [Installing Python Modules](#) for details. To install the latest version, run the following command

```
$ pip install -i https://pyq.enlnt.com --no-binary pyq pyq
```

Prerequisites

OS Support

PyQ has been tested and is supported on Linux and macOS 10.11 or later.

PyQ has support for Solaris, but has not been tested recently.

Windows is not supported yet.

Required Software

- [kdb+](#) 2.8 or later;
- Python 2.7, or 3.5 or later;
- GNU make, gcc or clang.

Installing from the package repository

Use following pip command to install the latest version of PyQ into your environment.

```
$ pip install -i https://pyq.enlnt.com --no-binary pyq pyq
```

To install another version, specify which version you would like to install:

```
$ pip install -i https://pyq.enlnt.com --no-binary pyq pyq==3.8
```

Installing from source code

1. Get the source code using one of the following:

- Clone the Github repository

```
$ git clone https://github.com/enlnt/pyq.git
```

- Download the source archive as a [tar file](#) or a [zip file](#) and extract it.

2. Install the sources into your environment using pip:

```
$ pip install <path to the source>
```

Installing PyQ into a virtual environment

PyQ was designed to work inside virtual environments. You can setup your system to use different versions of Python and/or kdb+ by using separate virtual environments.

In order to create a virtual environment, you need to install the [virtualenv](#) package:

```
$ [sudo] pip install virtualenv
```

Create a new virtualenv and activate it:

```
$ virtualenv path/to/virtualenv
$ source path/to/virtualenv/bin/activate
```

Download [kdb+](#) and save into your ~/Downloads folder. Extract it into virtualenv:

```
$ unzip ${HOME}/Downloads/macosx.zip -d ${VIRTUAL_ENV}
```

If you have licensed version of the kdb+, you should create directory for it first:

```
$ mkdir -p ${VIRTUAL_ENV}/q && unzip path/to/m64.zip -d ${VIRTUAL_ENV}/q
```

Copy your kdb+ license file to `${VIRTUAL_ENV}/q` or set the `QLIC` environment variable to the directory containing the license file and add it to the `virtualenv`'s `activate` file:

```
$ echo "export QLIC=path/to/qlic" >> ${VIRTUAL_ENV}/bin/activate
$ source ${VIRTUAL_ENV}/bin/activate
```

Install PyQ:

```
$ pip install -i https://pyq.enlnt.com --no-binary pyq pyq
```

Keeping PyQ up-to-date

You can upgrade PyQ to the latest version by running:

```
pip install -i https://pyq.enlnt.com --no-binary pyq -U pyq
```

Installing 32-bit PyQ with the free 32-bit kdb+ and Python 3.6 on 64-bit CentOS 7

Note: This guide was designed for installing Python 3.6. If you're looking to use Python 2.7, you can follow this guide by replacing `3.6.0` with `2.7.13` where necessary.

1. Install development tools and libraries required to build 32-bit Python

```
$ sudo yum install gcc gcc-c++ rpm-build subversion git zip unzip bzip2 \
libgcc.i686 glibc-devel.i686 glibc.i686 zlib-devel.i686 \
readline-devel.i686 gdbm-devel.i686 openssl-devel.i686 ncurses-devel.i686 \
tcl-devel.i686 libdb-devel.i686 bzip2-devel.i686 sqlite-devel.i686 \
tk-devel.i686 libpcap-devel.i686 xz-devel.i686 libffi-devel.i686
```

2. Download, compile and install the 32-bit version of Python 3.6.0

We are going to install Python 3.6 into `/opt/python3.6.i686`:

```
$ mkdir -p ${HOME}/Archive ${HOME}/Build
$ sudo mkdir -p /opt/python3.6.i686
$ curl -Ls http://www.python.org/ftp/python/3.6.0/Python-3.6.0.tgz \
-o ${HOME}/Archive/Python-3.6.0.tgz
$ tar xzvf ${HOME}/Archive/Python-3.6.0.tgz -C ${HOME}/Build
$ cd ${HOME}/Build/Python-3.6.0
$ export CFLAGS=-m32 LDFLAGS=-m32
$ ./configure --prefix=/opt/python3.6.i686 --enable-shared
$ LD_RUN_PATH=/opt/python3.6.i686/lib make
$ sudo make install
$ unset CFLAGS LDFLAGS
```

Let's confirm we have a 32-bit Python on our 64-bit system:

```
$ uname -mip
x86_64 x86_64 x86_64
$ /opt/python3.6.i686/bin/python3.6 \
```

```
-c "import platform; print(platform.processor(), platform.architecture())"
x86_64 ('32bit', 'ELF')
```

Yes, it is exactly what we desired.

3. Install virtualenv into Python installation

We are going to use virtual environments, download and extract virtualenv package:

```
$ curl -Ls https://pypi.org/packages/source/v/virtualenv/virtualenv-15.1.0.tar.gz \
-o ${HOME}/Archive/virtualenv-15.1.0.tar.gz
$ tar xzf ${HOME}/Archive/virtualenv-15.1.0.tar.gz -C ${HOME}/Build
```

4. Create 32-bit Python virtual environment

Create a virtual environment:

```
$ /opt/python3.6.i686/bin/python3.6 ${HOME}/Build/virtualenv-15.1.0/virtualenv.py \
${HOME}/Work/pyq3
```

Enter the virtual environment that we created, confirm that we have a 32-bit Python there:

```
(pyq3) $ source ${HOME}/Work/pyq3/bin/activate
(pyq3) $ python -c "import struct; print(struct.calcsize('P') * 8)"
32
```

5. Download the 32-bit Linux x86 version of kdb+ from kx.com

Download kdb+ by following [this link](#).

Save downloaded file as `${HOME}/Work/linux-x86.zip`.

6. Extract kdb+ and install PyQ

Extract downloaded file:

```
(pyq3) $ unzip ${HOME}/Work/linux-x86.zip -d ${VIRTUAL_ENV}
```

Install PyQ (note, PyQ 3.8.2 or newer required):

```
(pyq3) $ pip install -i https://pyq.enlnt.com --no-binary pyq pyq>=3.8.2
```

6. Use PyQ

Start PyQ:

```
(pyq3) $ pyq
```

```
>>> import platform
>>> platform.processor()
'x86_64'
>>> platform.architecture()
('32bit', 'ELF')
>>> from pyq import q
>>> q.til(10)
k('0 1 2 3 4 5 6 7 8 9')
```

Installing PyQ on Ubuntu 16.04

Since Python provided by Ubuntu is statically linked, shared libraries need to be installed before PyQ can be installed.

Python 2

Install shared libraries:

```
$ sudo apt-get install libpython-dev libpython-stdlib python-pip python-virtualenv
```

Create and activate virtual environment:

```
$ python -m virtualenv -p $(which python2) py2
$ source py2/bin/activate
```

Install PyQ:

```
(py2) $ pip install -i https://pyq.enlnt.com --no-binary pyq pyq
```

Python 3

Install shared libraries:

```
$ sudo apt-get install libpython3-dev libpython3-stdlib python3-pip python3-virtualenv
```

Create and activate virtual environment:

```
$ python3 -m virtualenv -p $(which python3) py3
$ source py3/bin/activate
```

Install PyQ:

```
(py3) $ pip3 install -i https://pyq.enlnt.com --no-binary pyq pyq
```

Installing PyQ on macOS

In order to use PyQ with the free 32-bit kdb+ on macOS, you need a 32-bit version of Python. Out of the box, macOS Sierra and High Sierra come with a universal version of Python 2.7.10.

System Python 2

Install virtualenv module:

```
$ pip install virtualenv
```

If your system, does not have pip installed, follow [pip installation guide](#).

Create and activate virtual environment:

```
$ virtualenv ${HOME}/pyq2
$ source ${HOME}/pyq2/bin/activate
```

Download [kdb+](#) by following [this link](#) and save the downloaded file as `${HOME}/Downloads/macosx.zip`.

Install kdb+ and PyQ:

```
(pyq2) $ unzip ${HOME}/Downloads/macosx.zip -d ${VIRTUAL_ENV}
(pyq2) $ pip install -i https://pyq.enlnt.com --no-binary pyq pyq
```

PyQ is ready and can be launched:

```
(pyq2) $ pyq
```

Brewing Universal Python

If you would like to use latest version of the Python 2.7 or Python 3, you will need to install it using package manager [Homebrew](#).

1. Install Homebrew. Installation instructions are available at [Homebrew's website](#).
2. Install universal Python 2.7 and Python 3.6:

```
$ brew install --universal sashkab/python/python27 sashkab/python/python36
```

3. Install virtualenv package.

```
$ /usr/local/opt/pythonXY/bin/pythonX -mpip install -U virtualenv
```

X is major version of the Python, *Y* - minor, i.e. 2.7 or 3.6.

4. Create new virtual environment and activate it:

```
$ mkvirtualenv -p /usr/local/opt/pythonXY/bin/pythonX ${HOME}/pyq
$ source ${HOME}/pyq/bin/activate
```

5. Download [kdb+](#) by following [this link](#) and save the downloaded file as `${HOME}/Downloads/macosx.zip`.

6. Install kdb+ and PyQ:

```
(pyq) $ unzip ${HOME}/Downloads/macosx.zip -d ${VIRTUAL_ENV}
(pyq) $ pip install -i https://pyq.enlnt.com --no-binary pyq pyq
```

PyQ is ready and can be launched:

```
(pyq2) $ pyq
```

Python for kdb+

Introduction

Kdb+, a high-performance database system comes with a programming language (q) that may be unfamiliar to many programmers. PyQ lets you enjoy the power of kdb+ in a comfortable environment provided by a mainstream programming language. In this guide we will assume that the reader has a working knowledge of Python, but we will explain the q language concepts as we encounter them.

The q namespace

Meet `q` - your portal to kdb+. Once you import `q` from `pyq`, you get access to over 170 functions:

```
>>> from pyq import q
>>> dir(q)
['abs', 'acos', 'aj', 'aj0', 'all', 'and_', 'any', 'asc', 'asin', ...]
```

These functions should be familiar to anyone who knows the q language and this is exactly what these functions are: q functions repackaged so that they can be called from Python. Some of the q functions are similar to Python builtins or `math` functions which is not surprising because q like Python is a complete general purpose language. In the following sections we will systematically draw an analogy between q and Python functions and explain the differences between them.

The til function

Since Python does not have a language constructs to loop over integers, many Python tutorials introduce the `range()` function early on. In the q language, the situation is similar and the function that produces a sequence of integers is called “til”. Mnemonically, `q.til(n)` means “Count from zero ‘til *n*”:

```
>>> q.til(10)
k('0 1 2 3 4 5 6 7 8 9')
```

The return value of a q function is always an instance of the class `K` which will be described in the next chapter. In the case of `q.til(n)`, the result is a `K` vector which is similar to Python list. In fact, you can get the Python list by simply calling the `list()` constructor on the q vector:

```
>>> list(_)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

While useful for illustrative purposes, you should avoid converting `K` vectors to Python lists in real programs. It is often more efficient to manipulate `K` objects directly. For example, unlike `range()`, `til()` does not have optional start or step arguments. This is not necessary because you can do arithmetic on the `K` vectors to achieve a similar result:

```
>>> range(10, 20, 2) == 10 + 2 * q.til(5)
True
```

Many q functions are designed to “map” themselves automatically over sequences passed as arguments. Those functions are called “atomic” and will be covered in the next section. The `til()` function is not atomic, but it can be mapped explicitly:

```
>>> q.til.each(range(5)).show()
`long$()
,0
0 1
0 1 2
0 1 2 3
```

The last example requires some explanation. First we have used the `show()` method to provide a nice multi-line display of a list of vectors. This method is available for all `K` objects. Second, the first line in the display shows an empty list of type “long”. Note that unlike Python lists `K` vectors come in different types and `til()` returns vectors of type “long”. Finally, the second line in the display starts with “,” to emphasize that this is a vector of size 1 rather than an atom.

The `each()` adverb is similar to Python’s `map()`, but is often much faster.

```
>>> q.til.each(range(5)) == map(q.til, range(5))
True
```

Atomic functions

As we mentioned in the previous section, atomic functions operate on numbers or lists of numbers. When given a number, an atomic function acts similarly to its Python analogue.

Compare

```
>>> q.exp(1)
k('2.718282')
```

and

```
>>> math.exp(1)
2.718281828459045
```

Note: Want to see more digits? Set `q` display precision using the `system()` function:

```
>>> q.system(b"P 16")
k('::')
>>> q.exp(1)
k('2.718281828459045')
```

Unlike their native Python analogues, atomic `q` functions can operate on sequences:

```
>>> q.exp(range(5))
k('1 2.718282 7.389056 20.08554 54.59815')
```

The result in this case is a `K` vector whose elements are obtained by applying the function to each element of the given sequence.

Mathematical functions

As you can see in the table below, most of the mathematical functions provided by `q` are similar to the Python standard library functions in the `math` module.

Table 1.1: Mathematical functions

q	Python	Return
<code>neg()</code>	<code>operator.neg()</code>	the negative of the argument
<code>abs()</code>	<code>abs()</code>	the absolute value
<code>signum()</code>		± 1 or 0 depending on the sign of the argument
<code>sqrt()</code>	<code>math.sqrt()</code>	the square root of the argument
<code>exp()</code>	<code>math.exp()</code>	e raised to the power of the argument
<code>log()</code>	<code>math.log()</code>	the natural logarithm (base e) of the argument
<code>cos()</code>	<code>math.cos()</code>	the cosine of the argument
<code>sin()</code>	<code>math.sin()</code>	the sine of the argument
<code>tan()</code>	<code>math.tan()</code>	the tangent of the argument
<code>acos()</code>	<code>math.acos()</code>	the arc cosine of the argument
<code>asin()</code>	<code>math.asin()</code>	the arc sine of the argument
<code>atan()</code>	<code>math.atan()</code>	the arc tangent of the argument
<code>ceiling()</code>	<code>math.ceil()</code>	the smallest integer \geq the argument
<code>floor()</code>	<code>math.floor()</code>	the largest integer \leq the argument
<code>reciprocal()</code>		1 divided by the argument

Other than being able to operate on lists of numbers, q functions differ from Python functions in a way they treat out of domain errors.

Where Python functions raise an exception,

```
>>> math.log(0)
Traceback (most recent call last):
...
ValueError: math domain error
```

q functions return special values:

```
>>> q.log([-1, 0, 1])
k('0n -0w 0')
```

The null function

Unlike Python, q allows division by zero. The reciprocal of zero is infinity that shows up as 0w or 0W in displays.

```
>>> q.reciprocal(0)
k('0w')
```

Multiplying infinity by zero produces a null value that generally indicates missing data

```
>>> q.reciprocal(0) * 0
k('0n')
```

Null values and infinities can also appear as a result of applying a mathematical function to numbers outside of its domain:

```
>>> q.log([-1, 0, 1])
k('0n -0w 0')
```

The `null()` function returns 1b (boolean true) when given a null value and 0b otherwise. For example, we applied to the output of the `log()` function from the previous example, it returns


```
>>> q.null(_)
k('100b')
```

Aggregation functions

Aggregation functions (also known as reduction functions) are functions that given a sequence of atoms produce an atom. For example,

```
>>> sum(range(10))
45
>>> q.sum(range(10))
k('45')
```

Table 1.2: Aggregation functions

q	Python	Return
<code>sum()</code>	<code>sum()</code>	the sum of the elements
<code>prd()</code>		the product of the elements
<code>all()</code>	<code>all()</code>	1b if all elements are nonzero, 0b otherwise
<code>any()</code>	<code>any()</code>	1b if any of the elements is nonzero, 0b otherwise
<code>min()</code>	<code>min()</code>	the smallest element
<code>max()</code>	<code>max()</code>	the largest element
<code>avg()</code>	<code>statistics.mean()</code>	the arithmetic mean
<code>var()</code>	<code>statistics.pvariance()</code>	the population variance
<code>dev()</code>	<code>statistics.pstdev()</code>	the square root of the population variance
<code>svar()</code>	<code>statistics.variance()</code>	the sample variance
<code>sdev()</code>	<code>statistics.stdev()</code>	the square root of the sample variance

Accumulation functions

Given a sequence of numbers, one may want to compute not just total sum, but all the intermediate sums as well. In q, this can be achieved by applying the `sums` function to the sequence:

```
>>> q.sums(range(10))
k('0 1 3 6 10 15 21 28 36 45')
```

Table 1.3: Accumulation functions

q	Return
<code>pyq.q.sums()</code>	the cumulative sums of the elements
<code>pyq.q.prds()</code>	the cumulative products of the elements
<code>pyq.q.maxs()</code>	the maximums of the prefixes of the argument
<code>pyq.q.mins()</code>	the minimums of the prefixes of the argument

There are no direct analogues of these functions in the Python standard library, but the `itertools.accumulate()` function provides similar functionality:

```
>>> list(itertools.accumulate(range(10)))
[0, 1, 3, 6, 10, 15, 21, 28, 36, 45]
```

Passing `operator.mul()`, `max()` or `min()` as the second optional argument to `itertools.accumulate()`, one can get analogues of `pyq.q.prds()`, `pyq.q.maxs()` and `pyq.q.mins()`.

Sliding window statistics

- `mavg()`
- `mcount()`
- `mdev()`
- `mmax()`
- `mmin()`
- `msum()`

Uniform functions

Uniform functions are functions that take a list and return another list of the same size.

- `reverse()`
- `ratios()`
- `deltas()`
- `differ()`
- `next()`
- `prev()`
- `fills()`

Set operations

- `except_()`
- `inter()`
- `union()`

Sorting and searching

Functions `asc()` and `desc()` sort lists in ascending and descending order respectively:

```
>>> a = [9, 5, 7, 3, 1]
>>> q.asc(a)
k('`s#1 3 5 7 9')
>>> q.desc(a)
k('9 7 5 3 1')
```

Note: The ``s#` prefix that appears in the display of the output for the `asc()` function indicates that the resulting vector has a sorted attribute set. An attribute can be queried by calling the `attr()` function or accessing the `attr` property of the result:

```
>>> s = q.asc(a)
>>> q.attr(s)
k('`s')
>>> s.attr
k('`s')
```

When the `asc()` function gets a vector with the `s` attribute set, it skips sorting and immediately returns the same vector.

Functions `iasc()` and `idesc()` return the indices indicating the order in which the elements of the incoming list should be taken to make them sorted:

```
>>> q.iasc(a)
k('4 3 1 2 0')
```

Sorted lists can be efficiently searched using `bin()` and `binr()` functions. As the names suggest, both use binary search to locate the position the element that is equal to the search key, but in the case when there is more than one such element, `binr()` returns the index of the first match while `bin()` returns the index of the last.

```
>>> q.binr([10, 20, 20, 20, 30], 20)
k('1')
>>> q.bin([10, 20, 20, 20, 30], 20)
k('3')
```

When no matching element can be found, `binr()` (`bin()`) returns the index of the position before (after) which the key can be inserted so that the list remains sorted.

```
>>> q.binr([10, 20, 20, 20, 30], [5, 15, 20, 25, 35])
k('0 1 1 4 5')
>>> q.bin([10, 20, 20, 20, 30], [5, 15, 20, 25, 35])
k('-1 0 3 3 4')
```

In the Python standard library similar functionality is provided by the `bisect` module.

```
>>> [bisect.bisect_left([10, 20, 20, 20, 30], key) for key in [5, 15, 20, 25, 35]]
[0, 1, 1, 4, 5]
>>> [-1 + bisect.bisect_right([10, 20, 20, 20, 30], key) for key in [5, 15, 20, 25, 35]]
[-1, 0, 3, 3, 4]
```

Note that while `binr()` and `bisect.bisect_left()` return the same values, `bin()` and `bisect.bisect_right()` are off by 1.

Q does not have a named function for searching in an unsorted list because it uses the `?` operator for that. We can easily expose this functionality in PyQ as follows:

```
>>> index = q('?')
>>> index([10, 30, 20, 40], [20, 25])
k('2 4')
```

Note that our home-brew `index` function is similar to the `list.index()` method, but it returns the one after last index when the key is not found while `list.index()` raises an exception.

```
>>> list.index([10, 30, 20, 40], 20)
2
>>> list.index([10, 30, 20, 40], 25)
Traceback (most recent call last):
...
ValueError: 25 is not in list
```

If you are not interested in the index, but only want to know whether the keys can be found in a list, you can use the `in_()` function:

```
>>> q.in_([20, 25], [10, 30, 20, 40])
k('10b')
```

Note: The `q.in_` function has a trailing underscore because otherwise it would conflict with the Python `in`.

From Python to kdb+

You can pass data from Python to kdb+ by assigning to `q` attributes. For example,

```
>>> q.i = 42
>>> q.a = [1, 2, 3]
>>> q.t = ('Python', 3.5)
>>> q.d = {'date': date(2012, 12, 12)}
>>> q.value.each(['i', 'a', 't', 'd']).show()
42
1 2 3
(`Python;3.5)
(,`date)!,2012.12.12
```

Note that Python objects are automatically converted to kdb+ form when they are assigned in the `q` namespace, but when they are retrieved, Python gets a “handle” to kdb+ data.

For example, passing an `int` to `q` results in

```
>>> q.i
k('42')
```

If you want a Python integer instead, you have to convert explicitly

```
>>> int(q.i)
42
```

This will be covered in more detail in the next section.

You can also create kdb+ objects by calling `q` functions that are also accessible as `q` attributes. For example,

```
>>> q.til(5)
k('0 1 2 3 4')
```

Some `q` functions don’t have names because `q` uses special characters. For example, to generate random data in `q` you should use the `?` function (operator). While PyQ does not supply a Python name for `?`, you can easily add it to your own toolkit:

```
>>> rand = q('?')
```

And use it as you would any other Python function

```
>>> x = rand(10, 2) # generates 10 random 0's or 1's (coin toss)
```

From kdb+ to Python

In many cases your data is already stored in kdb+ and PyQ philosophy is that it should stay there. Rather than converting kdb+ objects to Python, manipulating Python objects and converting them back to kdb+, PyQ lets you work directly with kdb+ data as if it was already in Python.

For example, let us retrieve the release date from kdb+:

```
>>> d1 = q('z.k')
```

add 30 days to get another date

```
>>> d2 = d1 + 30
```

and find the difference in whole weeks

```
>>> (d2 - d1) % 7
k('2')
```

Note that the result of operations are (handles to) kdb+ objects. The only exceptions to this rule are indexing and iteration over simple kdb+ vectors. These operations produce Python scalars

```
>>> list(q.a)
[1, 2, 3]
>>> q.a[-1]
3
```

In addition to Python operators, one invoke q functions on kdb+ objects directly from Python using convenient attribute access / method call syntax.

For example

```
>>> q.i.neg.exp.log.mod(5)
k('3f')
```

Note that the above is equivalent to

```
>>> q.mod(q.log(q.exp(q.neg(q.i))), 5)
k('3f')
```

but shorter and closer to q syntax

```
>>> q('(log exp neg i)mod 5')
k('3f')
```

The difference being that in q, functions are applied right to left, by in PyQ left to right.

Finally, if q does not provide the function that you need, you can unleash the full power of numpy or scipy on your kdb+ data.

```
>>> numpy.log2(q.a)
array([ 0.          ,  1.          ,  1.5849625])
```

Note that the result is a numpy array, but you can redirect the output back to kdb+. To illustrate this, create a vector of 0s in kdb+

```
>>> b = q.a * 0.0
```

and call a numpy function on one kdb+ object redirecting the output to another:

```
>>> numpy.log2(q.a, out=numpy.asarray(b))
```

The result of a numpy function is now in the kdb+ object

```
>>> b
k('0 1 1.584963')
```

Working with files

Kdb+ uses unmodified host file system to store data and therefore `q` has excellent support for working with files. Recall that we can send Python objects to kdb+ by simply assigning them to a `q` attribute:

```
>>> q.data = range(10)
```

This code saves 10 integers in kdb+ memory and makes a global variable `data` available to kdb+ clients, but it does not save the data in any persistent storage. To save `data` as a file “data”, we can simply call the `pyq.q.save` function as follows:

```
>>> q.save('data')
k('`:data')
```

Note that the return value of the `pyq.q.save` function is a `K` symbol that is formed by prepending ‘:’ to the file name. Such symbols are known as file handles in `q`. Given a file handle the kdb+ object stored in the file can be obtained by accessing the `value` property of the file handle:

```
>>> _.value
k('0 1 2 3 4 5 6 7 8 9')
```

Now we can delete the data from memory

```
>>> del q.data
```

and load it back from the file using the `pyq.q.load` function:

```
>>> q.load('data')
k('`:data')
>>> q.data
k('0 1 2 3 4 5 6 7 8 9')
```

`pyq.q.save` and `pyq.q.load` functions can also take a `pathlib.Path` object

```
>>> data_path = pathlib.Path('data')
>>> q.save(data_path)
k('`:data')
>>> q.load(data_path)
k('`:data')
>>> data_path.unlink()
```

It is not necessary to assign data to a global variable before saving it to a file. We can save our 10 integers directly to a file using the `pyq.q.set` function

```
>>> q.set('`:0-9', range(10))
k('`:0-9')
```

and read it back using the `pyq.q.set` function

```
>>> q.get(_)
k('0 1 2 3 4 5 6 7 8 9')
```

```
>>> pathlib.Path('0-9').unlink()
```

K objects

The q language has atoms (scalars), lists, dictionaries, tables and functions. In PyQ, kdb+ objects of any type appear as instances of class `K`. To tell the underlying kdb+ type, one can access the `type` property to obtain a type code. For example,

```
>>> vector = q.til(5); scalar = vector.first
>>> vector.type
k('7h')
>>> scalar.type
k('-7h')
```

Basic vector types have type codes in the range 1 through 19 and their elements have the type code equal to the negative of the vector type code. For the basic vector types, one can also get a human readable type name by accessing the `key` property:

```
>>> vector.key
k('`long')
```

To get the same from a scalar – convert it to a vector first:

```
>>> scalar.enlist.key
k('`long')
```

Table 1.4: Basic data types

Code	Kdb+ type	Python type
1	boolean	<code>bool</code>
2	guid	<code>uuid.UUID</code>
4	byte	
5	short	
6	int	
7	long	<code>int</code>
8	real	
9	float	<code>float</code>
10	char	<code>bytes (*)</code>
11	symbol	<code>str</code>
12	timestamp	
13	month	
14	date	<code>datetime.date</code>
16	timespan	<code>datetime.timedelta</code>
17	minute	
18	second	
19	time	<code>datetime.time</code>

(*) Unlike other Python types mentioned in the table above, `bytes` instances get converted to a vector type:

```
>>> K(b'x')
k('`x')
>>> q.type(_)
k('10h')
```

There is no scalar character type in Python, so in order to create a `K` character scalar, one will need to use a typed constructor:

```
>>> K.char(b'x')
k('x')
```

Typed constructors are discussed in the next section.

Constructors and casts

As we have seen in the previous chapter, it is often not necessary to construct `K` objects explicitly because they are automatically created whenever a Python object is passed to a `q` function. This is done by passing the Python object to the default `K` constructor.

For example, if you need to pass a type long atom to a `q` function, you can use a Python `int` instead, but if a different integer type is required, you will need to create it explicitly:

```
>>> K.short(1)
k('1h')
```

Since empty list does not know the element type, passing `[]` to the default `K` constructor produces a generic (type `0h`) list:

```
>>> K([])
k('()')
>>> q.type(_)
k('0h')
```

To create an empty list of a specific type – pass `[]` to one of the named constructors:

```
>>> K.time([])
k('`time$()')
```

Table 1.5: `K` constructors

Constructor	Accepts	Description
<code>K.boolean()</code>	<code>int, bool</code>	logical type <code>0b</code> is false and <code>1b</code> is true.
<code>byte()</code>	<code>int, bytes</code>	8-bit bytes
<code>short()</code>	<code>int</code>	16-bit integers
<code>int()</code>	<code>int</code>	32-bit integers
<code>long()</code>	<code>int</code>	64-bit integers
<code>real()</code>	<code>int, float</code>	32-bit floating point numbers
<code>float()</code>	<code>int, float</code>	32-bit floating point numbers
<code>char()</code>	<code>str, bytes</code>	8-bit characters
<code>symbol()</code>	<code>str, bytes</code>	interned strings
<code>timestamp()</code>	<code>int (nanoseconds), datetime</code>	date and time
<code>month()</code>	<code>int (months), date</code>	year and month
<code>date()</code>	<code>int (days), date</code>	year, month and day
<code>datetime()</code>		deprecated
<code>timespan()</code>	<code>int (nanoseconds), timedelta</code>	duration in nanoseconds
<code>minute()</code>	<code>int (minutes), time</code>	duration or time of day in minutes
<code>second()</code>	<code>int (seconds), time</code>	duration or time of day in seconds
<code>time()</code>	<code>int (milliseconds), time</code>	duration or time of day in milliseconds

The typed constructors can also be used to access infinities and missing values of the given type:


```
>>> K.real.na, K.real.inf
(k('0Ne'), k('0we'))
```

If you already have a `K` object and want to convert it to a different type, you can access the property named after the type name. For example,

```
>>> x = q.til(5)
>>> x.date
k('2000.01.01 2000.01.02 2000.01.03 2000.01.04 2000.01.05')
```

Operators

Both Python and `q` provide a rich system of operators. In PyQ, `K` objects can appear in many Python expressions where they often behave as native Python objects.

Most operators act on `K` instances as namesake `q` functions. For example:

```
>>> K(1) + K(2)
k('3')
```

The if statement and boolean operators

Python has three boolean operators `or`, `and` and `not` and `K` objects can appear in boolean expressions. The result of boolean expressions depends on how the objects are tested in Python if statements.

All `K` objects can be tested for “truth”. Similarly to the Python numeric types and sequences, `K` atoms of numeric types are true if they are not zero and vectors are true if they are non-empty.

Atoms of non-numeric types follow different rules. Symbols test true except for the empty symbol; characters and bytes tested true except for the null character/byte; guid, timestamp, and (deprecated) datetime types always test as true.

Functions test as true except for the monadic pass-through function:

```
>>> q('::') or q('+') or 1
k('+')
```

Dictionaries and tables are treated as sequences: they are true if non-empty.

Note that in most cases how the object test does not change when Python native types are converted to `K`:

```
>>> objects = [None, 1, 0, True, False, 'x', '', {1:2}, {}, date(2000, 1, 1)]
>>> [bool(o) for o in objects]
[False, True, False, True, False, True, False, True, False, True]
>>> [bool(K(o)) for o in objects]
[False, True, False, True, False, True, False, True, False, True]
```

One exception is the Python `time` type. Starting with version 3.5 all `time` instances test as true, but `time(0)` converts to `k('00:00:00.000')` which tests false:

```
>>> [bool(o) for o in (time(0), K(time(0)))]
[True, False]
```

Note: Python changed the rule for `time(0)` because `time` instances can be timezone aware and because they do not support addition making 0 less than special. Neither of those arguments apply to `q` time, second or minute data types which behave more like `timedelta`.

Arithmetic operations

Python has the four familiar arithmetic operators `+`, `-`, `*` and `/` as well as less common `**` (exponentiation), `%` (modulo) and `//` (floor division). PyQ maps those operators to `q` “verbs” as follows

Operation	Python	q
addition	<code>+</code>	<code>+</code>
subtraction	<code>-</code>	<code>-</code>
multiplication	<code>*</code>	<code>*</code>
true division	<code>/</code>	<code>%</code>
exponentiation	<code>**</code>	<code>xexp</code>
floor division	<code>//</code>	<code>div</code>
modulo	<code>%</code>	<code>mod</code>

K objects can be freely mixed with Python native types in arithmetic expressions and the result is a K object in most cases:

```
>>> q.til(10) % 3
k('0 1 2 0 1 2 0 1 2 0')
```

A notable exception occurs when the modulo operator is used for string formatting

```
>>> "%.5f" % K(3.1415)
'3.14150'
```

Unlike python sequences, K lists behave very similar to atoms: arithmetic operations act element-wise on them.

Compare

```
>>> [1, 2] * 5
[1, 2, 1, 2, 1, 2, 1, 2, 1, 2]
```

and

```
>>> K([1, 2]) * 5
k('5 10')
```

or

```
>>> [1, 2] + [3, 4]
[1, 2, 3, 4]
```

and

```
>>> K([1, 2]) + [3, 4]
k('4 6')
```

The flip (+) operator

The unary + operator acts as `flip()` function on `K` objects. Applied to atoms, it has no effect:

```
>>> +K(0)
k('0')
```

but it can be used to transpose a matrix:

```
>>> m = K([[1, 2], [3, 4]])
>>> m.show()
1 2
3 4
>>> (+m).show()
1 3
2 4
```

or turn a dictionary into a table:

```
>>> d = q('!', ['a', 'b'], m)
>>> d.show()
a| 1 2
b| 3 4
>>> (+d).show()
a b
---
1 3
2 4
```

Bitwise operators

Python has six bitwise operators: `|`, `^`, `&`, `<<`, `>>`, and `~`. Since there are no bitwise operations in `q`, PyQ redefines them as follows:

Operation	Result	Notes
<code>x y</code>	element-wise maximum of <i>x</i> and <i>y</i>	1.
<code>x ^ y</code>	<i>y</i> with null elements filled with <i>x</i>	2.
<code>x & y</code>	element-wise minimum of <i>x</i> and <i>y</i>	1.
<code>x << n</code>	<i>x</i> shifted left by <i>n</i> elements	3.
<code>x >> n</code>	<i>x</i> shifted right by <i>n</i> elements	3.
<code>~x</code>	a boolean vector with 1's for zero elements of <i>x</i>	

Notes:

1. For boolean vectors, `|` and `&` are also element-wise *or* and *and* operations.
2. For Python integers, the result of `x ^ y` is the bitwise exclusive or. There is no similar operation in `q`, but for boolean vectors exclusive or is equivalent to `q <>` (not equal).

3. Negative shift counts result in a shift in the opposite direction to that indicated by the operator: `x >> -n` is the same as `x << n`.

Minimum and maximum

Minimum and maximum operators are `&` and `|` in `q`. PyQ maps similar looking Python bitwise operators to the corresponding `q` ones:

```
>>> q.til(10) | 5
k('5 5 5 5 5 5 6 7 8 9')
>>> q.til(10) & 5
k('0 1 2 3 4 5 5 5 5 5')
```

The ^ operator

Unlike Python where caret (^) is the binary xor operator, `q` defines it to denote the [fill](#) operation that replaces null values in the right argument with the left argument. PyQ follows the `q` definition:

```
>>> x = q('1 0N 2')
>>> 0 ^ x
k('1 0 2')
```

The @ operator

Python 3.5 introduced the `@` operator that can be used by user types. Unlike `numpy` that defines `@` as the matrix multiplication operator, PyQ uses `@` for function application and composition:

```
>>> q.log @ q.exp @ 1
k('1f')
```

Adverbs

Adverbs in `q` are somewhat similar to Python decorators. They act on functions and produce new functions. The six adverbs are summarized in the table below.

Table 1.6: Adverbs

PyQ	q	Description
<code>K.each()</code>	<code>'</code>	map or case
<code>K.over()</code>	<code>/</code>	reduce
<code>K.scan()</code>	<code>\</code>	accumulate
<code>K.prior()</code>	<code>':</code>	each-prior
<code>K.sv()</code>	<code>/:</code>	each-right or scalar from vector
<code>K.vs()</code>	<code>\:</code>	each-left or vector from scalar

The functionality provided by the first three adverbs is similar to functional programming features scattered throughout Python standard library. Thus `each` is similar to `map()`. For example, given a list of lists of numbers

```
>>> data = [[1, 2], [1, 2, 3]]
```

One can do

```
>>> q.sum.each(data)
k('3 6')
```

or

```
>>> list(map(sum, [[1, 2], [1, 2, 3]]))
[3, 6]
```

and get similar results.

The over adverb is similar to the `functools.reduce()` function. Compare

```
>>> q(' ', ' ').over(data)
k('1 2 1 2 3')
```

and

```
>>> functools.reduce(operator.concat, data)
[1, 2, 1, 2, 3]
```

Finally, the scan adverb is similar to the `itertools.accumulate()` function.

```
>>> q(' ', ' ').scan(data).show()
1 2
1 2 1 2 3
```

```
>>> for x in itertools.accumulate(data, operator.concat):
...     print(x)
...
[1, 2]
[1, 2, 1, 2, 3]
```

Each

The each adverb serves double duty in q. When it is applied to a function, it returns a new function that expects lists as arguments and maps the original function over those lists. For example, we can write a “daily return” function in q that takes yesterday’s price as the first argument (x), today’s price as the second (y) and dividend as the third (z) as follow:

```
>>> r = q('{(y+z-x)%x}') # Recall that % is the division operator in q.
```

and use it to compute returns from a series of prices and dividends using `r.each`:

```
>>> p = [50.5, 50.75, 49.8, 49.25]
>>> d = [.0, .0, 1.0, .0]
>>> r.each(q.prev(p), p, d)
k('0n 0.004950495 0.0009852217 -0.01104418')
```

When the each adverb is applied to an integer vector, it turns the vector `v` into an `n`-ary function that for each `i`-th argument selects its `v[i]`-th element. For example,

```
>>> v = q.til(3)
>>> v.each([1, 2, 3], 100, [10, 20, 30])
k('1 100 30')
```

Note that scalars passed to `v.each` are treated as infinitely repeated values. Vector arguments must all be of the same length.

Over and scan

Given a function `f`, `f.over` and `f.scan` adverbs are similar as both apply `f` repeatedly, but `f.over` only returns the final result, while `f.scan` returns all intermediate values as well.

For example, recall that the Golden Ratio can be written as a continued fraction as follows

$$\phi = 1 + \frac{1}{1 + \frac{1}{1 + \dots}}$$

or equivalently as the limit of the sequence that can be obtained by starting with 1 and repeatedly applying the function

$$f(x) = 1 + \frac{1}{1 + x}$$

The numerical value of the Golden Ratio can be found as

$$\phi = \frac{1 + \sqrt{5}}{2} \approx 1.618033988749895$$

```
>>> phi = (1+math.sqrt(5)) / 2
>>> phi
1.618033988749895
```

Function `f` can be written in `q` as follows:

```
>>> f = q('{1+reciprocal x}')
```

and

```
>>> f.over(1.)
k('1.618034')
```

indeed yields a number recognizable as the Golden Ratio. If instead of `f.over`, we compute `f.scan`, we will get the list of all convergents.

```
>>> x = f.scan(1.)
>>> len(x)
32
```

Note that `f.scan` (and `f.over`) stop calculations when the next iteration yields the same value and indeed `f` applied to the last value returns the same value:

```
>>> f(x.last) == x.last
True
```

which is close to the value computed using the exact formula

```
>>> math.isclose(x.last, phi)
True
```

The number of iterations can be given explicitly by passing two arguments to `f.scan` or `f.over`:

```
>>> f.scan(10, 1.)
k('1 2 1.5 1.666667 1.6 1.625 1.615385 1.619048 1.617647 1.618182 1.617978')
>>> f.over(10, 1.)
k('1.617978')
```

This is useful when you need to iterate a function that does not converge.

Continuing with the Golden Ratio theme, let's define a function

```
>>> f = q('{(last x;sum x)}')
```

that given a pair of numbers returns another pair made out of the last and the sum of the numbers in the original pair. Iterating this function yields the Fibonacci sequence

```
>>> x = f.scan(10, [0, 1])
>>> q.first.each(x)
k('0 1 1 2 3 5 8 13 21 34 55')
```

and the ratios of consecutive Fibonacci numbers form the sequence of Golden Ratio convergents that we have seen before:

```
>>> q.ratios(_)
k('0 0w 1 2 1.5 1.666667 1.6 1.625 1.615385 1.619048 1.617647')
```

Each previous

In the previous section we have seen a function `ratios()` that takes a vector and produces the ratios of the adjacent elements. A similar function called `deltas()` produces the differences between the adjacent elements:

```
>>> q.deltas([1, 3, 2, 5])
k('1 2 -1 3')
```

These functions are in fact implemented in `q` by applying the `prior` adverb to the division (`%`) and subtraction functions respectively:

```
>>> q.ratios == q('%').prior and q.deltas == q('-').prior
True
```

In general, for any binary function f and a vector v

$$f.prior(v) = (f(v_1, v_0), f(v_2, v_1), \dots)$$

Adverbs vs and sv

Of all adverbs, these two have the most cryptic names and offer some non-obvious features.

To illustrate how `vs` and `sv` modify binary functions, let's give a Python name to the `q` operator:

```
>>> join = q(',')
```

Suppose you have a list of file names

```
>>> name = K.string(['one', 'two', 'three'])
```

and an extension

```
>>> ext = K.string(".py")
```

You want to append the extension to each name on your list. If you naively call `join` on `name` and `ext`, the result will not be what you might expect:

```
>>> join(name, ext)
k('("one";"two";"three";".";"p";"y")')
```

This happened because `join` treated `ext` as a list of characters rather than an atomic string and created a mixed list of three strings followed by three characters. What we need is to tell `join` to treat its first argument as a vector and the second as a scalar and this is exactly what the `vs` adverb will achieve:

```
>>> join.vs(name, ext)
k('("one.py";"two.py";"three.py")')
```

The mnemonic rule is “vs” = “vector, scalar”. Now, if you want to prepend a directory name to each resulting file, you can use the `sv` attribute:

```
>>> d = K.string("/tmp/")
>>> join.sv(d, _)
k('("/tmp/one.py";"/tmp/two.py";"/tmp/three.py")')
```

Input/Output

```
>>> import os
>>> r, w = os.pipe()
>>> h = K(w) (kp("xyz"))
>>> os.read(r, 100)
b'xyz'
>>> os.close(r); os.close(w)
```

Q variables can be accessed as attributes of the ‘q’ object:

```
>>> q.t = q('([a:1 2i;b:`x`y)')
>>> sum(q.t.a)
3
>>> del q.t
```

Numeric Computing

NumPy is the fundamental package for scientific computing in Python. NumPy shares common APL ancestry with `q` and can often operate directly on `K` objects.

Primitive data types

There are eighteen primitive data types in `kdb+`, eight of those closely match their NumPy analogues and will be called “simple types” in this section. Simple types consist of booleans, bytes, characters, integers of three different sizes, and floating point numbers of two sizes. Seven `kdb+` types are dealing with dates, times and durations. Similar data types are available in recent versions of NumPy, but they differ from `kdb+` types in many details. Finally, `kdb+` symbol, enum and guid types have no direct analogue in NumPy.

Table 1.7: Primitive kdb+ data types as NumPy arrays

No.	kdb+ type	array type	raw	description
1	boolean	bool_	bool_	Boolean (True or False) stored as a byte
2	guid	uint8 (x16)	uint8 (x16)	Globally unique 16-byte identifier
4	byte	uint8	uint8	Byte (0 to 255)
5	short	int16	int16	Signed 16-bit integer
6	int	int32	int32	Signed 32-bit integer
7	long	int64	int64	Signed 64-bit integer
8	real	float32	float32	Single precision 32-bit float
9	float	float64	float64	Double precision 64-bit float
10	char	S1	S1	(byte-)string
11	symbol	str	P	Strings from a pool
12	timestamp	datetime64[ns]	int64	Date and time with nanosecond resolution
13	month	datetime64[M]	int32	Year and month
14	date	datetime64[D]	int32	Date (year, month, day)
16	timespan	timedelta64[ns]	int64	Time duration in nanoseconds
17	minute	datetime64[m]	int32	Time duration (or time of day) in minutes
18	second	datetime64[s]	int32	Time duration (or time of day) in seconds
19	time	datetime64[ms]	int32	Time duration (or time of day) in milliseconds
20+	enum	str	int32	Enumerated strings

Simple types

Kdb+ atoms and vectors of the simple types (booleans, characters, integers and floats) can be viewed as 0- or 1-dimensional NumPy arrays. For example,

```
>>> x = K.real([10, 20, 30])
>>> a = numpy.asarray(x)
>>> a.dtype
dtype('float32')
```

Note that `a` in the example above is not a copy of `x`. It is an array view into the same data:

```
>>> a.base.obj
k('10 20 30e')
```

If you modify `a`, you modify `x` as well:

```
>>> a[:] = 88
>>> x
k('88 88 88e')
```

Dates, times and durations

An age old question of when to start counting calendar years did not get any easier in the computer age. Python standard `date` starts at

```
>>> date.min
datetime.date(1, 1, 1)
```

more commonly known as

```
>>> date.min.strftime('%B %d, %Y')
'January 01, 0001'
```

and this date is considered to be day 1

```
>>> date.min.toordinal()
1
```

Note that according to the Python calendar the world did not exist before that date:

```
>>> date.fromordinal(0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: ordinal must be >= 1
```

At the time of this writing,

```
>>> date.today().toordinal()
736335
```

The designer of kdb+ made a more practical choice for date 0 to be January 1, 2000. As a result, in PyQ we have

```
>>> K.date(0)
k('2000.01.01')
```

and

```
>>> (-2 + q.til(5)).date
k('1999.12.30 1999.12.31 2000.01.01 2000.01.02 2000.01.03')
```

Similarly, the 0 timestamp was chosen to be at midnight of the day 0

```
>>> K.timestamp(0)
k('2000.01.01D00:00:00.000000000')
```

NumPy, however the third choice was made. Kowtowing to the UNIX tradition, NumPy took midnight of January 1, 1970 as the zero mark on its timescales.

```
>>> numpy.array([0], 'datetime64[D]')
array(['1970-01-01'], dtype='datetime64[D]')
>>> numpy.array([0], 'datetime64[ns]')
array(['1970-01-01T00:00:00.000000000'], dtype='datetime64[ns]')
```

PyQ will automatically adjust the epoch when converting between NumPy arrays and K objects.

```
>>> d = q.til(2).date
>>> a = numpy.array(d)
>>> d
k('2000.01.01 2000.01.02')
>>> a
array(['2000-01-01', '2000-01-02'], dtype='datetime64[D]')
>>> K(a)
k('2000.01.01 2000.01.02')
```

This convenience comes at a cost of copying the data

```
>>> a[0] = 0
>>> a
array(['1970-01-01', '2000-01-02'], dtype='datetime64[D]')
>>> d
k('2000.01.01 2000.01.02')
```

To avoid such copying, K objects can expose their raw data to numpy:

```
>>> b = numpy.asarray(d.data)
>>> b.tolist()
[0, 1]
```

Arrays created this way share their data with the underlying K objects. Any change to the array is reflected in kdb+.

```
>>> b[:] += 42
>>> d
k('2000.02.12 2000.02.13')
```

Characters, strings and symbols

Text data appears in kdb+ as character atoms and strings or as symbols and enumerations. Character strings are compatible with NumPy “bytes” type:

```
>>> x = K.string("abc")
>>> a = numpy.asarray(x)
>>> a.dtype.type
<class 'numpy.bytes_'>
```

In the example above, data is shared between the kdb+ string `x` and NumPy array `a`:

```
>>> a[:] = 'x'
>>> x
k('"xxx"')
```

Nested lists

Kdb+ does not have a data type representing multi-dimensional contiguous arrays. In PyQ, a multi-dimensional NumPy array becomes a nested list when passed to `q` functions or converted to K objects. For example,

```
>>> a = numpy.arange(12, dtype=float).reshape((2,2,3))
>>> x = K(a)
>>> x
k('((0 1 2f;3 4 5f);(6 7 8f;9 10 11f))')
```

Similarly, kdb+ nested lists of regular shape, become multi-dimensional NumPy arrays when passed to `numpy.array()`:

```
>>> numpy.array(x)
array([[ 0.,  1.,  2.],
       [ 3.,  4.,  5.],
       [ 6.,  7.,  8.],
       [ 9., 10., 11.]])
```

Moreover, many NumPy functions can operate directly on kdb+ nested lists, but they internally create a contiguous copy of the data

```
>>> numpy.mean(x, axis=2)
array([[ 1.,  4.],
       [ 7., 10.]])
```

Tables and dictionaries

Unlike kdb+ NumPy does not implement column-wise tables. Instead it has record arrays that can store table-like data row by row. PyQ supports two-way conversion between kdb+ tables and NumPy record arrays:

```
>>> trades.show()
sym time size
-----
a 09:31 100
a 09:33 300
b 09:32 200
b 09:35 100
```

```
>>> numpy.array(trades)
array([('a', datetime.timedelta(0, 34260), 100),
      ('a', datetime.timedelta(0, 34380), 300),
      ('b', datetime.timedelta(0, 34320), 200),
      ('b', datetime.timedelta(0, 34500), 100)],
      dtype=[('sym', 'O'), ('time', '<m8[m]'), ('size', '<i8')])
```

Enhanced shell

If you have ipython installed in your environment, you can run an interactive IPython shell as follows:

```
$ pyq -m IPython
```

For a better experience, load `pyq.magic` extension:

```
In [1]: %load_ext pyq.magic
```

This makes K objects display nicely in the output and gives you access to the PyQ-specific IPython magic commands:

Line magic `%q`:

```
In [2]: %q ([a:til 3;b:10*til 3])
Out[2]:
a b
----
0 0
1 10
2 20
```

Cell magic `%%q`:

```
In [4]: %%q
....: a: exec a from t where b=20
....: b: exec b from t where a=2
....: a+b
```

```
.....:
Out[4]: ,22
```

You can pass following options to the %%q cell magic:

```
-l (dirlscript)
    pre-load database or script
-h host:port
    execute on the given host
-o var
    send output to a variable named var
-i var1, ..., varN
    input variables
-l
    redirect stdout
-2
    redirect stderr
```

q) prompt

While in PyQ, you can drop to emulated kdb+ Command Line Interface (CLI). Here is how:

Start pyq:

```
$ pyq
>>> from pyq import q
```

Enter kdb+ CLI:

```
>>> q()
q)t:([a:til 5; b:10*til 5)
q)t
a b
----
0 0
1 10
2 20
3 30
4 40
```

Exit back to Python:

```
q) \
>>> print("Back to Python")
Back to Python
```

Or you can exit back to shell:

```
q) \
$
```

Calling Python from KDB+

KDB+ is designed as a platform for multiple programming languages. Out of the box, it comes with q and K distributes variant of ANSI SQL as the “s” language. Installing pyq gives access to the “p” language, where “p” obviously stands for “Python”. In addition, PyQ provides a mechanism for exporting Python functions to q where they can be called as native q functions.

The “p” language

To access Python from the q) prompt, simply start the line with the p) prefix and follow with the Python statement(s). Since the standard q) prompt does not allow multi-line entries, you are limited to what can be written in one line and need to separate python statements with semicolons.

```
q)p) x = 42; print(x)
42
```

The p) prefix can also be used in q scripts. In this case, multi-line python statements can be used as long as additional lines start with one or more spaces. For example, with the following code in hello.q

```
p)def f():
    print('Hello')
p)f()
```

we get

```
$ q hello.q -q
Hello
```

If your script contains more python code than q, you can avoid sprinkling it with p) ‘s by placing the code in a file with .p extension. Thus instead of hello.q described above, we can write the following code in hello.p

```
def f():
    print('Hello')
f()
q.exit(0)
```

and run it the same way:

```
$ q hello.p -q
Hello
```

It is recommended that any substantial amount of Python code be placed in regular python modules or packages with only top level entry points imported and called in q scripts.

Exporting Python functions to q

As we have seen in the previous section, calling python by evaluating “p)” expressions has several limitations. For tighter integration between q and Python, pyq supports exporting Python functions to q. Once exported, python functions appear in q as monadic functions that take a single argument that should be a list. For example, we can make Python’s %-formatting available in q as follows:

```
>>> def fmt(f, x):
...     return K.string(str(f) % x)
>>> q.fmt = fmt
```

Now, calling the `fmt` function from `q` will pass the argument list to Python and return the result back to `q`:

```
q)fmt ("%10.6f";acos -1)
"  3.141593"
```

Python functions exported to `q` should return a `K` object or an instance of one of the simple scalar types: `None`, `bool`, `int`, `float` or `str` which are automatically converted to `q` : `:`, `boolean`, `long`, `float` or `symbol` respectively.

Exported functions are called from `q` by supplying a single argument that contains a list of objects to be passed to the Python functions as `K`-valued arguments.

Note: To pass a single argument to an exported function, it has to be enlisted. For example,

```
q)p)q.erf = math.erf
q)erf enlist 1
0.8427008
```

Reference Manual

(This section is generated from the PyQ source code. You can access most of this material using `pydoc` or the built-in `help` method.)

`K`

`q`

class K

`K.abs()`

absolute value

For details, see [q.abs](#) and [abs on code.kx.com](#).

`K.acos()`

arc cosine

For details, see [q.acos](#) and [acos on code.kx.com](#).

`K.aj()`

as-of join

For details, see [q.aj](#) and [aj on code.kx.com](#).

`K.aj0()`

as-of join

For details, see [q.aj0](#) and [aj on code.kx.com](#).

`K.all()`

all nonzero

For details, see [q.all](#) and [all on code.kx.com](#).

`K.and_()`

and

For details, see [q.and_](#) and [and on code.kx.com](#).

- K.any()**
any item is non-zero
For details, see [q.any](#) and [any](#) on [code.kx.com](#).
- K.asc()**
ascending sort
For details, see [q.asc](#) and [asc](#) on [code.kx.com](#).
- K.asin()**
arc sine
For details, see [q.asin](#) and [asin](#) on [code.kx.com](#).
- K.asof()**
as-of operator
For details, see [q.asof](#) and [asof](#) on [code.kx.com](#).
- K.atan()**
arc tangent
For details, see [q.atan](#) and [atan](#) on [code.kx.com](#).
- K.attr()**
attributes
For details, see [q.attr](#) and [attr](#) on [code.kx.com](#).
- K.avg()**
arithmetic mean
For details, see [q.avg](#) and [avg](#) on [code.kx.com](#).
- K.avgs()**
running averages
For details, see [q.avgs](#) and [avgs](#) on [code.kx.com](#).
- K.bin()**
binary search
For details, see [q.bin](#) and [bin](#) on [code.kx.com](#).
- K.binr()**
binary search
For details, see [q.binr](#) and [bin](#) on [code.kx.com](#).
- K.ceiling()**
lowest integer above
For details, see [q.ceiling](#) and [ceiling](#) on [code.kx.com](#).
- K.cols()**
column names of a table
For details, see [q.cols](#) and [cols](#) on [code.kx.com](#).
- K.cor()**
correlation
For details, see [q.cor](#) and [cor](#) on [code.kx.com](#).

- K.cos()**
cosine
For details, see [q.cos](#) and [cos](#) on [code.kx.com](#).
- K.count()**
number of items
For details, see [q.count](#) and [count](#) on [code.kx.com](#).
- K.cov()**
statistical covariance
For details, see [q.cov](#) and [cov](#) on [code.kx.com](#).
- K.cross()**
cross product
For details, see [q.cross](#) and [cross](#) on [code.kx.com](#).
- K.csv()**
comma delimiter
For details, see [q.csv](#) and [csv](#) on [code.kx.com](#).
- K.cut()**
cut
For details, see [q.cut](#) and [cut](#) on [code.kx.com](#).
- K.deltas()**
differences between consecutive pairs
For details, see [q.deltas](#) and [deltas](#) on [code.kx.com](#).
- K.desc()**
descending sort
For details, see [q.desc](#) and [desc](#) on [code.kx.com](#).
- K.dev()**
standard deviation
For details, see [q.dev](#) and [dev](#) on [code.kx.com](#).
- K.differ()**
flag differences in consecutive pairs
For details, see [q.differ](#) and [differ](#) on [code.kx.com](#).
- K.distinct()**
unique items
For details, see [q.distinct](#) and [distinct](#) on [code.kx.com](#).
- K.div()**
integer division
For details, see [q.div](#) and [div](#) on [code.kx.com](#).
- K.dsave()**
save global tables to disk
For details, see [q.dsave](#) and [dsave](#) on [code.kx.com](#).

- K.ej()**
equi-join
For details, see [q.ej](#) and [ej](#) on [code.kx.com](#).
- K.ema()**
exponentially-weighted moving average
For details, see [q.ema](#) and [ema](#) on [code.kx.com](#).
- K.ema()**
exponentially-weighted moving average
For details, see [q.ema](#) and [ema](#) on [code.kx.com](#).
- K.enlist()**
arguments as a list
For details, see [q.enlist](#) and [enlist](#) on [code.kx.com](#).
- K.eval()**
evaluate a parse tree
For details, see [q.eval](#) and [eval](#) on [code.kx.com](#).
- K.except_()**
left argument without items in right argument
For details, see [q.except_](#) and [except](#) on [code.kx.com](#).
- K.exp()**
power of e
For details, see [q.exp](#) and [exp](#) on [code.kx.com](#).
- K.fby()**
filter-by
For details, see [q.fby](#) and [fby](#) on [code.kx.com](#).
- K.fills()**
forward-fill nulls
For details, see [q.fills](#) and [fills](#) on [code.kx.com](#).
- K.first()**
first item
For details, see [q.first](#) and [first](#) on [code.kx.com](#).
- K.fkeys()**
foreign-key columns mapped to their tables
For details, see [q.fkeys](#) and [fkeys](#) on [code.kx.com](#).
- K.flip()**
transpose
For details, see [q.flip](#) and [flip](#) on [code.kx.com](#).
- K.floor()**
greatest integer less than argument
For details, see [q.floor](#) and [floor](#) on [code.kx.com](#).

- K.get()**
get
For details, see [q.get](#) and [get](#) on [code.kx.com](#).
- K.getenv()**
value of an environment variable
For details, see [q.getenv](#) and [getenv](#) on [code.kx.com](#).
- K.group()**
dictionary of distinct items
For details, see [q.group](#) and [group](#) on [code.kx.com](#).
- K.gtime()**
UTC timestamp
For details, see [q.gtime](#) and [gtime](#) on [code.kx.com](#).
- K.hclose()**
close a file or process
For details, see [q.hclose](#) and [hclose](#) on [code.kx.com](#).
- K.hcount()**
size of a file
For details, see [q.hcount](#) and [hcount](#) on [code.kx.com](#).
- K.hdel()**
delete a file
For details, see [q.hdel](#) and [hdel](#) on [code.kx.com](#).
- K.hopen()**
open a file
For details, see [q.hopen](#) and [hopen](#) on [code.kx.com](#).
- K.hsym()**
convert symbol to filename or IP address
For details, see [q.hsym](#) and [hsym](#) on [code.kx.com](#).
- K.iasc()**
indices of ascending sort
For details, see [q.iasc](#) and [iasc](#) on [code.kx.com](#).
- K.idesc()**
indices of descending sort
For details, see [q.idesc](#) and [idesc](#) on [code.kx.com](#).
- K.ij()**
inner join
For details, see [q.ij](#) and [ij](#) on [code.kx.com](#).
- K.ijf()**
The `ijf` function.
For details, see [q.ijf](#) and [ijf](#) on [code.kx.com](#).

- K.in_()**
membership
For details, see [q.in_](#) and [in](#) on [code.kx.com](#).
- K.insert()**
append records to a table
For details, see [q.insert](#) and [insert](#) on [code.kx.com](#).
- K.inter()**
items common to both arguments
For details, see [q.inter](#) and [inter](#) on [code.kx.com](#).
- K.inv()**
matrix inverse
For details, see [q.inv](#) and [inv](#) on [code.kx.com](#).
- K.key()**
key
For details, see [q.key](#) and [key](#) on [code.kx.com](#).
- K.keys()**
names of a table's columns
For details, see [q.keys](#) and [keys](#) on [code.kx.com](#).
- K.last()**
last item
For details, see [q.last](#) and [last](#) on [code.kx.com](#).
- K.like()**
pattern matching
For details, see [q.like](#) and [like](#) on [code.kx.com](#).
- K.lj()**
left join
For details, see [q.lj](#) and [lj](#) on [code.kx.com](#).
- K.ljf()**
left join
For details, see [q.ljf](#) and [ljf](#) on [code.kx.com](#).
- K.load()**
load binary data
For details, see [q.load](#) and [load](#) on [code.kx.com](#).
- K.log()**
natural logarithm
For details, see [q.log](#) and [log](#) on [code.kx.com](#).
- K.lower()**
lower case
For details, see [q.lower](#) and [lower](#) on [code.kx.com](#).

- K.lsq()**
least squares matrix divide
For details, see [q.lsq](#) and [lsq](#) on [code.kx.com](#).
- K.ltime()**
local timestamp
For details, see [q.ltime](#) and [ltime](#) on [code.kx.com](#).
- K.ltrim()**
function remove leading spaces
For details, see [q.ltrim](#) and [ltrim](#) on [code.kx.com](#).
- K.mavg()**
moving average
For details, see [q.mavg](#) and [mavg](#) on [code.kx.com](#).
- K.max()**
maximum
For details, see [q.max](#) and [max](#) on [code.kx.com](#).
- K.maxs()**
maxima of preceding items
For details, see [q.maxs](#) and [maxs](#) on [code.kx.com](#).
- K.mcount()**
moving count
For details, see [q.mcount](#) and [mcount](#) on [code.kx.com](#).
- K.md5()**
MD5 hash
For details, see [q.md5](#) and [md5](#) on [code.kx.com](#).
- K.mdev()**
moving deviation
For details, see [q.mdev](#) and [mdev](#) on [code.kx.com](#).
- K.med()**
median
For details, see [q.med](#) and [med](#) on [code.kx.com](#).
- K.meta()**
metadata of a table
For details, see [q.meta](#) and [meta](#) on [code.kx.com](#).
- K.min()**
minimum
For details, see [q.min](#) and [min](#) on [code.kx.com](#).
- K.mins()**
minimum of preceding items
For details, see [q.mins](#) and [mins](#) on [code.kx.com](#).

- K.mmax()**
moving maxima
For details, see [*q.mmax*](#) and [mmax on code.kx.com](#).
- K.mmin()**
moving minima
For details, see [*q.mmin*](#) and [mmin on code.kx.com](#).
- K.mmu()**
mmu
For details, see [*q.mmu*](#) and [mmu on code.kx.com](#).
- K.mod()**
remainder
For details, see [*q.mod*](#) and [mod on code.kx.com](#).
- K.msum()**
moving sum
For details, see [*q.msum*](#) and [msum on code.kx.com](#).
- K.neg()**
negate
For details, see [*q.neg*](#) and [neg on code.kx.com](#).
- K.next()**
next items
For details, see [*q.next*](#) and [next on code.kx.com](#).
- K.not_()**
not
For details, see [*q.not_*](#) and [not on code.kx.com](#).
- K.null()**
null
For details, see [*q.null*](#) and [null on code.kx.com](#).
- K.or_()**
or
For details, see [*q.or_*](#) and [or on code.kx.com](#).
- K.parse()**
parse a string
For details, see [*q.parse*](#) and [parse on code.kx.com](#).
- K.peach()**
peach
For details, see [*q.peach*](#) and [peach on code.kx.com](#).
- K.pj()**
plus join
For details, see [*q.pj*](#) and [pj on code.kx.com](#).

- K.prd()**
product
For details, see [q.prd](#) and [prd](#) on [code.kx.com](#).
- K.prds()**
cumulative products
For details, see [q.prds](#) and [prds](#) on [code.kx.com](#).
- K.prev()**
previous items
For details, see [q.prev](#) and [prev](#) on [code.kx.com](#).
- K.prior()**
prior
For details, see [q.prior](#) and [prior](#) on [code.kx.com](#).
- K.rand()**
random number
For details, see [q.rand](#) and [rand](#) on [code.kx.com](#).
- K.rank()**
grade up
For details, see [q.rank](#) and [rank](#) on [code.kx.com](#).
- K.ratios()**
ratios of consecutive pairs
For details, see [q.ratios](#) and [ratios](#) on [code.kx.com](#).
- K.raze()**
join items
For details, see [q.raze](#) and [raze](#) on [code.kx.com](#).
- K.read0()**
read file as lines
For details, see [q.read0](#) and [read0](#) on [code.kx.com](#).
- K.read1()**
read file as bytes
For details, see [q.read1](#) and [read1](#) on [code.kx.com](#).
- K.reciprocal()**
reciprocal of a number
For details, see [q.reciprocal](#) and [reciprocal](#) on [code.kx.com](#).
- K.reval()**
variation of eval
For details, see [q.reval](#) and [reval](#) on [code.kx.com](#).
- K.reverse()**
reverse the order of items
For details, see [q.reverse](#) and [reverse](#) on [code.kx.com](#).

- K.rload()**
load a splayed table
For details, see [q.rload](#) and [rload on code.kx.com](#).
- K.rotate()**
rotate items
For details, see [q.rotate](#) and [rotate on code.kx.com](#).
- K.rsave()**
rsave
For details, see [q.rsave](#) and [rsave on code.kx.com](#).
- K.rtrim()**
remove trailing spaces
For details, see [q.rtrim](#) and [rtrim on code.kx.com](#).
- K.save()**
save global data to file
For details, see [q.save](#) and [save on code.kx.com](#).
- K.scov()**
statistical covariance
For details, see [q.scov](#) and [scov on code.kx.com](#).
- K.scov()**
statistical covariance
For details, see [q.scov](#) and [scov on code.kx.com](#).
- K.sdev()**
statistical standard deviation
For details, see [q.sdev](#) and [sdev on code.kx.com](#).
- K.sdev()**
statistical standard deviation
For details, see [q.sdev](#) and [sdev on code.kx.com](#).
- K.set()**
set
For details, see [q.set](#) and [set on code.kx.com](#).
- K.setenv()**
set an environment variable
For details, see [q.setenv](#) and [setenv on code.kx.com](#).
- K.show()**
format to the console
For details, see [q.show](#) and [show on code.kx.com](#).
- K.signum()**
sign of its argument/s
For details, see [q.signum](#) and [signum on code.kx.com](#).

K.sin()
sine

For details, see [*q.sin*](#) and [sin](#) on [code.kx.com](#).

K.sqrt()
square root

For details, see [*q.sqrt*](#) and [sqrt](#) on [code.kx.com](#).

K.ss()
string search

For details, see [*q.ss*](#) and [ss](#) on [code.kx.com](#).

K.ssr()
string search and replace

For details, see [*q.ssr*](#) and [ssr](#) on [code.kx.com](#).

K.string()
cast to string

For details, see [*q.string*](#) and [string](#) on [code.kx.com](#).

K.sublist()
sublist of a list

For details, see [*q.sublist*](#) and [sublist](#) on [code.kx.com](#).

K.sum()
sum of a list

For details, see [*q.sum*](#) and [sum](#) on [code.kx.com](#).

K.sums()
cumulative sums of a list

For details, see [*q.sums*](#) and [sums](#) on [code.kx.com](#).

K.sv()
consolidate

For details, see [*q.sv*](#) and [sv](#) on [code.kx.com](#).

K.svar()
statistical variance

For details, see [*q.svar*](#) and [svar](#) on [code.kx.com](#).

K.svar()
statistical variance

For details, see [*q.svar*](#) and [svar](#) on [code.kx.com](#).

K.system()
system

For details, see [*q.system*](#) and [system](#) on [code.kx.com](#).

K.tables()
sorted list of tables

For details, see [*q.tables*](#) and [tables](#) on [code.kx.com](#).

- K.tan()**
tangent
For details, see [q.tan](#) and [tan](#) on [code.kx.com](#).
- K.til()**
integers up to x
For details, see [q.til](#) and [til](#) on [code.kx.com](#).
- K.trim()**
remove leading and trailing spaces
For details, see [q.trim](#) and [trim](#) on [code.kx.com](#).
- K.type()**
data type
For details, see [q.type](#) and [type](#) on [code.kx.com](#).
- K.uj()**
union join
For details, see [q.uj](#) and [uj](#) on [code.kx.com](#).
- K.ujf()**
The ujf function.
For details, see [q.ujf](#) and [ujf](#) on [code.kx.com](#).
- K.ungroup()**
flattened table
For details, see [q.ungroup](#) and [ungroup](#) on [code.kx.com](#).
- K.union()**
distinct items of combination of two lists
For details, see [q.union](#) and [union](#) on [code.kx.com](#).
- K.upper()**
upper-case
For details, see [q.upper](#) and [upper](#) on [code.kx.com](#).
- K.upsert()**
add table records
For details, see [q.upsert](#) and [upsert](#) on [code.kx.com](#).
- K.value()**
value
For details, see [q.value](#) and [value](#) on [code.kx.com](#).
- K.var()**
variance
For details, see [q.var](#) and [var](#) on [code.kx.com](#).
- K.view()**
definition of a dependency
For details, see [q.view](#) and [view](#) on [code.kx.com](#).

- K.views()**
list of defined views
For details, see [q.views](#) and views on code.kx.com.
- K.vs()**
split
For details, see [q.vs](#) and vs on code.kx.com.
- K.wavg()**
weighted average
For details, see [q.wavg](#) and wavg on code.kx.com.
- K.where()**
replicated items
For details, see [q.where](#) and where on code.kx.com.
- K.within()**
flag items within range
For details, see [q.within](#) and within on code.kx.com.
- K.wj()**
window join
For details, see [q.wj](#) and wj on code.kx.com.
- K.wj1()**
window join
For details, see [q.wj1](#) and wj1 on code.kx.com.
- K.wsum()**
weighted sum
For details, see [q.wsum](#) and wsum on code.kx.com.
- K.ww()**
The ww function.
For details, see [q.ww](#) and ww on code.kx.com.
- K.xasc()**
table sorted ascending by columns
For details, see [q.xasc](#) and xasc on code.kx.com.
- K.xbar()**
interval bar
For details, see [q.xbar](#) and xbar on code.kx.com.
- K.xcol()**
rename table columns
For details, see [q.xcol](#) and xcol on code.kx.com.
- K.xcols()**
re-order table columns
For details, see [q.xcols](#) and xcols on code.kx.com.

- K.xdesc()**
table sorted descending by columns
For details, see [q.xdesc](#) and [xdesc](#) on [code.kx.com](#).
- K.xexp()**
raised to a power
For details, see [q.xexp](#) and [xexp](#) on [code.kx.com](#).
- K.xgroup()**
table grouped by keys
For details, see [q.xgroup](#) and [xgroup](#) on [code.kx.com](#).
- K.xkey()**
set primary keys of a table
For details, see [q.xkey](#) and [xkey](#) on [code.kx.com](#).
- K.xlog()**
base-x logarithm
For details, see [q.xlog](#) and [xlog](#) on [code.kx.com](#).
- K.xprev()**
previous items
For details, see [q.xprev](#) and [xprev](#) on [code.kx.com](#).
- K.xrank()**
items assigned to buckets
For details, see [q.xrank](#) and [xrank](#) on [code.kx.com](#).

namespace q

`pyq.q`

Q functions

- q.abs()**
absolute value The abs function computes the absolute value of its argument. Null is returned if the argument is null.

```
>>> q.abs([-1, 0, 1, None])  
k('1 0 1 0N')
```

See also [abs](#) on [code.kx.com](#).

- q.acos()**
arc cosine
See also [acos](#) on [code.kx.com](#).

- q.aj()**
as-of join
See also [aj](#) on [code.kx.com](#).

`q.aj0()`
as-of join
See also [aj](#) on [code.kx.com](#).

`q.all()`
all nonzero
See also [all](#) on [code.kx.com](#).

`q.and_()`
and
See also [and](#) on [code.kx.com](#).

`q.any()`
any item is non-zero
See also [any](#) on [code.kx.com](#).

`q.asc()`
ascending sort
See also [asc](#) on [code.kx.com](#).

`q.asin()`
arc sine
See also [asin](#) on [code.kx.com](#).

`q.asof()`
as-of operator
See also [asof](#) on [code.kx.com](#).

`q.atan()`
arc tangent
See also [atan](#) on [code.kx.com](#).

`q.attr()`
attributes
See also [attr](#) on [code.kx.com](#).

`q.avg()`
arithmetic mean
See also [avg](#) on [code.kx.com](#).

`q.avgs()`
running averages
See also [avgs](#) on [code.kx.com](#).

`q.bin()`
binary search
See also [bin](#) on [code.kx.com](#).

`q.binr()`
binary search
See also [bin](#) on [code.kx.com](#).

- `q. ceiling()`
lowest integer above
See also [ceiling on code.kx.com](#).
- `q.cols()`
column names of a table
See also [cols on code.kx.com](#).
- `q.cor()`
correlation
See also [cor on code.kx.com](#).
- `q.cos()`
cosine
See also [cos on code.kx.com](#).
- `q.count()`
number of items
See also [count on code.kx.com](#).
- `q.cov()`
statistical covariance
See also [cov on code.kx.com](#).
- `q.cross()`
cross product
See also [cross on code.kx.com](#).
- `q.csv()`
comma delimiter
See also [csv on code.kx.com](#).
- `q.cut()`
cut
See also [cut on code.kx.com](#).
- `q.deltas()`
differences between consecutive pairs
See also [deltas on code.kx.com](#).
- `q.desc()`
descending sort
See also [desc on code.kx.com](#).
- `q.dev()`
standard deviation
See also [dev on code.kx.com](#).
- `q.differ()`
flag differences in consecutive pairs
See also [differ on code.kx.com](#).

- `q.distinct()`
unique items
See also [distinct on code.kx.com](#).
- `q.div()`
integer division
See also [div on code.kx.com](#).
- `q.dsave()`
save global tables to disk
See also [dsave on code.kx.com](#).
- `q.ej()`
equi-join
See also [ej on code.kx.com](#).
- `q.ema()`
exponentially-weighted moving average
See also [ema on code.kx.com](#).
- `q.ema()`
exponentially-weighted moving average
See also [ema on code.kx.com](#).
- `q.enlist()`
arguments as a list
See also [enlist on code.kx.com](#).
- `q.eval()`
evaluate a parse tree
See also [eval on code.kx.com](#).
- `q.except_()`
left argument without items in right argument
See also [except on code.kx.com](#).
- `q.exp()`
power of e
See also [exp on code.kx.com](#).
- `q.fby()`
filter-by
See also [fby on code.kx.com](#).
- `q.fills()`
forward-fill nulls
See also [fills on code.kx.com](#).
- `q.first()`
first item
See also [first on code.kx.com](#).

`q.fkeys()`
foreign-key columns mapped to their tables

See also [fkeys on code.kx.com](#).

`q.flip()`
transpose

See also [flip on code.kx.com](#).

`q.floor()`
greatest integer less than argument

See also [floor on code.kx.com](#).

`q.get()`
get

See also [get on code.kx.com](#).

`q.getenv()`
value of an environment variable

See also [getenv on code.kx.com](#).

`q.group()`
dictionary of distinct items

See also [group on code.kx.com](#).

`q.gtime()`
UTC timestamp

See also [gtime on code.kx.com](#).

`q.hclose()`
close a file or process

See also [hclose on code.kx.com](#).

`q.hcount()`
size of a file

See also [hcount on code.kx.com](#).

`q.hdel()`
delete a file

See also [hdel on code.kx.com](#).

`q.hopen()`
open a file

See also [hopen on code.kx.com](#).

`q.hsym()`
convert symbol to filename or IP address

See also [hsym on code.kx.com](#).

`q.iasc()`
indices of ascending sort

See also [iasc on code.kx.com](#).

`q.idesc()`
indices of descending sort
See also [idesc on code.kx.com](#).

`q.ij()`
inner join
See also [ij on code.kx.com](#).

`q.ijf()`
The `ijf` function.
See also [ijf on code.kx.com](#).

`q.in_()`
membership
See also [in on code.kx.com](#).

`q.insert()`
append records to a table
See also [insert on code.kx.com](#).

`q.inter()`
items common to both arguments
See also [inter on code.kx.com](#).

`q.inv()`
matrix inverse
See also [inv on code.kx.com](#).

`q.key()`
key
See also [key on code.kx.com](#).

`q.keys()`
names of a table's columns
See also [keys on code.kx.com](#).

`q.last()`
last item
See also [last on code.kx.com](#).

`q.like()`
pattern matching
See also [like on code.kx.com](#).

`q.lj()`
left join
See also [lj on code.kx.com](#).

`q.ljf()`
left join
See also [ljf on code.kx.com](#).

- `q.load()`
load binary data
See also [load on code.kx.com](#).
- `q.log()`
natural logarithm
See also [log on code.kx.com](#).
- `q.lower()`
lower case
See also [lower on code.kx.com](#).
- `q.lsqr()`
least squares matrix divide
See also [lsqr on code.kx.com](#).
- `q.ltime()`
local timestamp
See also [ltime on code.kx.com](#).
- `q.ltrim()`
function remove leading spaces
See also [ltrim on code.kx.com](#).
- `q.mavg()`
moving average
See also [mavg on code.kx.com](#).
- `q.max()`
maximum
See also [max on code.kx.com](#).
- `q.maxs()`
maxima of preceding items
See also [maxs on code.kx.com](#).
- `q.mcount()`
moving count
See also [mcount on code.kx.com](#).
- `q.md5()`
MD5 hash
See also [md5 on code.kx.com](#).
- `q.mdev()`
moving deviation
See also [mdev on code.kx.com](#).
- `q.med()`
median
See also [med on code.kx.com](#).

`q.meta()`
metadata of a table
See also [meta](#) on [code.kx.com](#).

`q.min()`
minimum
See also [min](#) on [code.kx.com](#).

`q.mins()`
minimum of preceding items
See also [mins](#) on [code.kx.com](#).

`q.mmax()`
moving maxima
See also [mmax](#) on [code.kx.com](#).

`q.mmin()`
moving minima
See also [mmin](#) on [code.kx.com](#).

`q.mmu()`
mmu
See also [mmu](#) on [code.kx.com](#).

`q.mod()`
remainder
See also [mod](#) on [code.kx.com](#).

`q.msum()`
moving sum
See also [msum](#) on [code.kx.com](#).

`q.neg()`
negate
See also [neg](#) on [code.kx.com](#).

`q.next()`
next items
See also [next](#) on [code.kx.com](#).

`q.not_()`
not
See also [not](#) on [code.kx.com](#).

`q.null()`
null
See also [null](#) on [code.kx.com](#).

`q.or_()`
or
See also [or](#) on [code.kx.com](#).

`q.parse()`
parse a string

See also [parse](#) on [code.kx.com](#).

`q.peach()`
peach

See also [peach](#) on [code.kx.com](#).

`q.pj()`
plus join

See also [pj](#) on [code.kx.com](#).

`q.prd()`
product

See also [prd](#) on [code.kx.com](#).

`q.prds()`
cumulative products

See also [prds](#) on [code.kx.com](#).

`q.prev()`
previous items

See also [prev](#) on [code.kx.com](#).

`q.prior()`
prior

See also [prior](#) on [code.kx.com](#).

`q.rand()`
random number

See also [rand](#) on [code.kx.com](#).

`q.rank()`
grade up

See also [rank](#) on [code.kx.com](#).

`q.ratios()`
ratios of consecutive pairs

See also [ratios](#) on [code.kx.com](#).

`q.raze()`
join items

See also [raze](#) on [code.kx.com](#).

`q.read0()`
read file as lines

See also [read0](#) on [code.kx.com](#).

`q.read1()`
read file as bytes

See also [read1](#) on [code.kx.com](#).

- `q.reciprocal()`
reciprocal of a number
See also [reciprocal on code.kx.com](#).
- `q.reval()`
variation of eval
See also [reval on code.kx.com](#).
- `q.reverse()`
reverse the order of items
See also [reverse on code.kx.com](#).
- `q.rload()`
load a splayed table
See also [rload on code.kx.com](#).
- `q.rotate()`
rotate items
See also [rotate on code.kx.com](#).
- `q.rsave()`
rsave
See also [rsave on code.kx.com](#).
- `q.rtrim()`
remove trailing spaces
See also [rtrim on code.kx.com](#).
- `q.save()`
save global data to file
See also [save on code.kx.com](#).
- `q.scov()`
statistical covariance
See also [scov on code.kx.com](#).
- `q.scov()`
statistical covariance
See also [scov on code.kx.com](#).
- `q.sdev()`
statistical standard deviation
See also [sdev on code.kx.com](#).
- `q.sdev()`
statistical standard deviation
See also [sdev on code.kx.com](#).
- `q.set()`
set
See also [set on code.kx.com](#).

- `q.setenv()`
set an environment variable
See also [setenv on code.kx.com](#).
- `q.show()`
format to the console
See also [show on code.kx.com](#).
- `q.signum()`
sign of its argument/s
See also [signum on code.kx.com](#).
- `q.sin()`
sine
See also [sin on code.kx.com](#).
- `q.sqrt()`
square root
See also [sqrt on code.kx.com](#).
- `q.ss()`
string search
See also [ss on code.kx.com](#).
- `q.ssr()`
string search and replace
See also [ssr on code.kx.com](#).
- `q.string()`
cast to string
See also [string on code.kx.com](#).
- `q.sublist()`
sublist of a list
See also [sublist on code.kx.com](#).
- `q.sum()`
sum of a list
See also [sum on code.kx.com](#).
- `q.sums()`
cumulative sums of a list
See also [sums on code.kx.com](#).
- `q.sv()`
consolidate
See also [sv on code.kx.com](#).
- `q.svar()`
statistical variance
See also [svar on code.kx.com](#).

- `q.svar()`
statistical variance
See also [svar on code.kx.com](#).
- `q.system()`
system
See also [system on code.kx.com](#).
- `q.tables()`
sorted list of tables
See also [tables on code.kx.com](#).
- `q.tan()`
tangent
See also [tan on code.kx.com](#).
- `q.til()`
integers up to x
See also [til on code.kx.com](#).
- `q.trim()`
remove leading and trailing spaces
See also [trim on code.kx.com](#).
- `q.type()`
data type
See also [type on code.kx.com](#).
- `q.uj()`
union join
See also [uj on code.kx.com](#).
- `q.ujf()`
The `ujf` function.
See also [ujf on code.kx.com](#).
- `q.ungroup()`
flattened table
See also [ungroup on code.kx.com](#).
- `q.union()`
distinct items of combination of two lists
See also [union on code.kx.com](#).
- `q.upper()`
upper-case
See also [upper on code.kx.com](#).
- `q.upsert()`
add table records
See also [upsert on code.kx.com](#).

`q.value()`
value

See also [value on code.kx.com](#).

`q.var()`
variance

See also [var on code.kx.com](#).

`q.view()`
definition of a dependency

See also [view on code.kx.com](#).

`q.views()`
list of defined views

See also [views on code.kx.com](#).

`q.vs()`
split

See also [vs on code.kx.com](#).

`q.wavg()`
weighted average

See also [wavg on code.kx.com](#).

`q.where()`
replicated items

See also [where on code.kx.com](#).

`q.within()`
flag items within range

See also [within on code.kx.com](#).

`q.wj()`
window join

See also [wj on code.kx.com](#).

`q.wj1()`
window join

See also [wj1 on code.kx.com](#).

`q.wsum()`
weighted sum

See also [wsum on code.kx.com](#).

`q.ww()`
The ww function.

See also [ww on code.kx.com](#).

`q.xasc()`
table sorted ascending by columns

See also [xasc on code.kx.com](#).

- `q.xbar()`
interval bar
See also [xbar on code.kx.com](#).
- `q.xcol()`
rename table columns
See also [xcol on code.kx.com](#).
- `q.xcols()`
re-order table columns
See also [xcols on code.kx.com](#).
- `q.xdesc()`
table sorted descending by columns
See also [xdesc on code.kx.com](#).
- `q.xexp()`
raised to a power
See also [xexp on code.kx.com](#).
- `q.xgroup()`
table grouped by keys
See also [xgroup on code.kx.com](#).
- `q.xkey()`
set primary keys of a table
See also [xkey on code.kx.com](#).
- `q.xlog()`
base-x logarithm
See also [xlog on code.kx.com](#).
- `q.xprev()`
previous items
See also [xprev on code.kx.com](#).
- `q.xrank()`
items assigned to buckets
See also [xrank on code.kx.com](#).

Version History

PyQ 4.1.1

Released on 2017-09-21

Bug fixes and enhancements

- !579 - BUG #948 Fixed compile errors on Windows with kdb+ version < 3.5.
- !577 - BUG #946 Fixed compilation errors for Python 2.7 on Windows.
- !582 - ENH #950 Explain how to properly start PyQ when launching from stock Python.

Documentation

- !583 - DOC #951 Updated links to the new kx.com website.

CI

- !584 - TST #952 Attempt to fix failing tests on Windows.

PyQ 4.1.0

Released on 2017-08-30

New features

- !519 - #889: Multi-threading support.
- !542 - #917: traceback support.
- **Experimental Windows support**
 - !507 - #900: Windows support.
 - !508 - #900: Windows support py36.
 - !527 - #900: Fixed a few tests that failed under Windows.
 - !562 - BLD #934 windows ci.
 - !564 - TST #900 Fix/skip tests that fail on Windows.

Enhancements

- !503, !568 - #659: New setup.py
- !560 - ENH #933 Use dot(K, K) for kdb+ versions ≥ 3.5
- !558 - #880 Fix ktd bug
- !552 - TST #920 Test $\pm 0Wt$ conversions to Python.
- !550 - ENH #925 Define Q_VERSION and similar constants in _k.c.
- !549 - ENH #925: Define QVER once, use everywhere.
- !548 - ENH #924 Allow returning arbitrary objects from python calls.
- !545 - ENH #921 Handle passing keyword arguments to functions in C.
- !544 - #919: Remove x2l objects
- !520 - #615: BUG: Empty symbol list converts to float array.

Kx

- !539, !569 - Updated k.h.
- !566 - #937 Add Apache 2.0 license for kx owned components.

Documentation

- !510 - Use locally stored intersphinx inventory.
- !515 - #895: PyQ 4.0 presentation
- !532 - #914: Use new kx.code.com
- !553 - DOC #805 Updated the description in the README file.
- !554 - DOC #805 Added links to long description.

- !557 - DOC #929 Add macOS installation instructions
- !572 - DOC #890 What's new in 4.1.

CI

- !513 - #904 Add Centos 7 x64 docker image to CI runs
- !559 - BLD #935 Change default kdb+ version to 3.5.
- !561 - TST #930 Test 64-bit installation on macOS.
- !565 - BLD #938 Blacklist pytest 3.2.0, due to a bug.
- !570 - BLD Closes #940 Test using Python 2.7, 3.5 and 3.6; numpy 1.12 and 1.13.
- !571 - BLD #867 Add setup option when we remove setuptools.
- !531 - #909 Added ubuntu job to CI in develop branch

PyQ 4.0.3

Released on 2017-07-17

Bug fixes:

- !551 - BUG #922: Allow large ($> 2^{31}$) integers in `K._ktn()`.
- !546 - BUG #923 Fixed conversion of mixed lists.

Documentation:

- !547 - DOC: Minor documentation corrections

PyQ 4.0.2

Released on 2017-05-12

Enhancements:

- !523 - #909: Support installing PyQ on Ubuntu 16.04.
- !528 - #911: qp and pq: set console size in q when running ptpython scripts.
- !535 - #910: qp: exit from q) prompt on Ctrl-D.
- !536 - #912: qp: report error and exit if pre-loading fails.

Documentation:

- !537 - #909: Added a guide on installing PyQ on Ubuntu.
- !533 - #914: Use new `kx.code.com`.

PyQ 4.0.1

Released on 2017-03-15

Enhancements:

- !509 - #903: Fixed a reference leak in debug build and a gcc 4.8.5 compiler warning.
- !505 - #901: Provide a fallback for systems that lack `CPU_COUNT`, e.g. RHEL 5.

- !502 - #899: Corrected integer types on 32-bit systems and added explicit casts when necessary.

Documentation:

- !511 - Use locally stored intersphinx inventory.
- !506 - #902 Updated README.

PyQ 4.0

Released on 2017-03-02

New Features:

- !365 - #756: Expose okx from k.h in Python.
- !376 - #806: Hooked basic prompt toolkit functionality into cmdtloop.
- !384 - #809: Implemented the qp script - like pq but start at the q) prompt.
- !385 - #806: Add bottom toolbar to q) prompt.
- !378 - #809: Implemented ipyq and pq scripts.
- !387 - #813: Implemented the @ operator.
- !401 - #828: Implemented type-0 list to array conversions.
- !402 - #775: Implemented getitem for enumerated lists.
- !404 - #833: Implemented *K.__sizeof__()* method.
- !359 - #642: Implement typed constructors and casts
- !390 - #815: Implemented the data attribute for the K objects in C.
- !396 - #829: Implemented basic nd > 1 case: C contiguous and simple type.
- !410 - #840: Implemented shift operators.
- !420 - #851: Implemented setm() and m9() in _k.
- !422 - #852: Implemented conversion from arbitrary sequences to K.
- !428 - #835: Implemented *K.__rmatmul__*.
- !432 - #856: Implemented file system path protocol for file handles.
- !435 - #598: Added support for pathlib2.
- !437 - #855: Added support for complex numbers.
- !439 - #791: Implemented _n attribute for K objects.
- !467 - #873: Implement *K.timespan(int)* constructor

Enhancements:

- !297 - #752: More datetime64 to q conversions
- !314 - #672: Improve calling Python functions from q
- !315 - #766: Defined the *__dir__* method for class _Q.
- !316 - #767: Make “exec” method callable without trailing _ in PY3K
- !330 - #779: Reimplemented new and call in C
- !352 - #792: Restore support for KXVER=2.

- !354 - #796: Conversion of “small” kdb+ longs will now produce Python ints under Python 2.x.
- !355 - #769: Restore array struct
- !358 - #798: Revisit array to k conversions.
- !375 - #791: K object attributes
- !377 - #807: Clean up and reuse the list of q functions between K and q
- !379 - #808: Clean up pyq namespace
- !380 - #791: Replaced `.inspect(b't')` with `._t`.
- !381 - #806: Return to Python prompt when Control-D or Control-C is pressed.
- !382 - #659: Get rid of KXVER in the C module name.
- !383 - #810: Clean up q namespace
- !388 - #779, #798: Removed unused variables.
- !389 - #818: Use fully qualified name for the internal K base class.
- !391 - #816: temporal data lists to array conversion
- !394 - #823: Preload kdb+ database if provided on pyq command line.
- !397 - #830: Make sure strings obtained from q symbols are interned.
- !398 - #806: Added a simple word completer.
- !399 - #819: Make `K.string` accept unicode in Python 2.x and bytes in Python 3.x.
- !400 - #806: Clean python exit on \
- !405 - #836: Reimplemented `K.__bool__` in C.
- !406 - #837: Reimplemented `K.__get__` in C.
- !408 - #838: Install sphinxcontrib-spelling package in the deploy stage.
- !413 - #842: K to bytes conversion
- !423 - #852: Added special treatment of symbols in `_from_sequence()`; allow mixed lists in conversions.
- !424 - #852: Fixed the case of empty sequence. Use `K._from_sequence` as a tuple converter.
- !425 - #852: Remove dict workaround
- !426 - #853: Make `dict[i]` consistent with `list[i]`
- !429 - #854: Walk up the mro to discover converters
- !430 - #608: Return K from mixed K - numpy array operations.
- !431 - #679: Fixed conversion of enumeration scalars into strings.
- !442 - #808: pyq globals clean-up
- !443 - #858: The “nil” object does not crash `show()` anymore.
- !444 - #817: Clip `int(q('0N'))` to -0W when building `K.long` lists.
- !445 - #857: Adverbs revisited
- !446 - #861: Allow unary and binary ops and projections to be called with keywords.
- !447 - #857: Use `vs (sv)` instead of `each_left(right)`.
- !449 - #864: Corrected the date bounds and added a comprehensive test.

- !450 - #865: Fixed x.char cast
- !455 - #863: Allow out-of-range scalar dates to be converted to $\pm 0Wd$.
- !460 - #870: K.timestamp bug
- !470 - #874: K.boolean redesign
- !477 - #875: Make sure bool(enum scalar) works in various exotic scenarios.
- !481 - #881: K._ja bug
- !483 - #850: Use py2x converters in atom constructors.
- !485 - #882: Return 0w on overflow
- !486 - #883: Make boolean constructor stricter : Allow only integer-like values in K._kb().
- !487 - #884: Detect mappings in typed constructors.
- !490 - #841: Fixed mv_release.
- !492 - #886: Fix two bugs in pyq executable; improve setup tests
- !494 - #891: Fix crash in K._kc()

CI and tests improvements:

- !349, !456, !456, !471, !457, !459, !464 - #695, #793, #867: Improvements in code coverage reporting.
- !350 - #794: Run pycodestyle in tox.
- !411 - #827: Use Python 3.6 and 2.7.13 in CI.
- !415, !451 - #845: Use Docker for CI
- !433 - #679: Fixed test on kdb+ 2.x.
- !436 - Add numpy 1.12 to the CI tests.
- !440 - #803: keywords and descriptions from code.kx.com.
- !452 - Add kdb+ 3.5t to the CI tests.
- !461 - #866: Added tests and fixed timestamp range.
- !475 - Use random CPU and limit one CPU core per job in CI.
- !489 - #885: Reformatted code in test files.
- !318, !351, !474, !478, !479, !480, !484, !488, !491 - #768: Improve C code test coverage.

Documentation:

- !341 - #789: Updated README: Test section.
- !353 - #764: simpler docstrings
- !360 - #764: Reorganized documentation. Minor fixes.
- !361 - #764: More docs improvements
- !362 - #764: docs improvements
- !366 - #764: test docs build in tox
- !371 - #803: Updated 32-bit Python/PyQ guide to use Python 3.6.
- !374 - #804: doc style improvements
- !373 - #764 and #777 table to array and sphinx doctest

- !392 - #820: What's New in 4.0
- !403 - #832: spellcheck docs
- !407 - #838: Add doc path to sys.path in conf.py.
- !409 - #803 Docs additions
- !412 - #803: Make documentation testing a separate stage.
- !427 - #803: more docs
- !448 - #803: More docs
- !469 - #871: More docs
- !438 - #854 (#820): Added a what's new entry about named tuples conversion.
- !472 - #803: Added adverbs documentation
- !493 - #803: Document calling Python from q
- !462, !463, !465, !468, !473 - Logo improvements

Setup:

- !337 - #782: Use install extras to install requirements.
- !339 - #782: Use extras instead of deps in tox.ini.
- !340 - #788: Add ipython extras.

PyQ 3.8.5

Released on 2017-03-16

- !517 - #901: Provide a fallback for systems that lack CPU_COUNT.

PyQ 3.8.4

Released on 2017-01-13

- !414 - #843: Setup should not fail if VIRTUAL_ENV is undefined
- !395 - #825: Fixed uninitialized “readonly” field in getbuffer

PyQ 3.8.3

Released on 2016-12-15

- !357 - #799: Several documentation fixes.
- !368 - #802: Setup should not fail if \$VIRTUAL_ENV/q does not exist.

PyQ 3.8.2

Released on 2016-12-01

Documentation improvements:

- !306 - #763: Update README.md - fixed INSTALL link.

- !312 - Fix formatting; ?? -> date of the release in the CHANGELOG.
- !322 - Fixed formatting error in the documentation.
- !324 - #744: use pip to install from the source.
- !338 - #785: Virtual environment setup guide.
- !346 - #764: docs improvements
- !342 - #787: Added links to rtd documentation.

PyQ executable improvements:

- !310 - #761: Allow PyQ executable to be compiled as 32-bit on 64-bit platform.
- !329 - #646: Print PyQ, KDB+ and Python versions if `--versions` option is given to `pyq`.
- !332 - #646: Print full PyQ version.
- !333 - #781: Find QHOME when `q` is installed next to `bin/pyq` but no `venv` is set.
- !336 - #783: Fixed a bug in CPUS processing
- !345 - #646: Added NumPy version to `--versions` output.

Other improvements and bug fixes:

- !308 - #759: Return an empty slice when `(stop - start) // stride < 0`.
- !320 - #771: Workaround for `OrderedDict` bug in Python 3.5
- !323 - #773: Renamed `ipython` into `jupyter`; added starting notebook command.
- !326 - #720: Simplified the test demonstrating the difference in Python 2 and 3 behaviors.
- !327 - #720: Finalize embedded Python interpreter on exit from `q`.
- !331, !343 - #768: Improve C coverage

Improvement in the (internal) CI:

- !305, !309, !311, !321, !335, !347 - Multiple improvements in the CI.
- !319 - #770: Run doctests in `tox`.

PyQ 3.8.1

Released on 2016-06-21

- !292 - #744: Print guessed path of `q` executable when `exec` fails.
- !293, !294 - #748 Use `VIRTUAL_ENV` environment variable to guess QHOME.
- !301, !295 - #751: Update documentation.
- !296 - #750: Fall back on 32-bit version of `q` if 64-bit version does not run.
- !298, !299, !300, !303 - #753: CI Improvements.
- !302 - #755: Use `preserveEnumerations=1` option to `b9` instead of `-1`.

PyQ 3.8

Released on 2016-04-26.

- !256 - #670: Enable 32-bit CI
- !258 - #717 Expose sd0 and sd1 in python.
- !259 - #718 Added a test running “q test.p”.
- !261 - Use Python 3.4.3 in CI
- !272, !273 - #731 Added Python 3.5.0 test environment and other CI improvements.
- !263 - #718 More p) tests
- !264 - #709 Redirect stderr and stdout to notebook
- !271 - #729 Conversion of lists of long integers to q.
- !274 - #728 Don’t corrupt existing QHOME while running tox.
- !275 - #733 Don’t add second soabi for Python 3.5.
- !276 - #734: Added support for enums in memoryview.
- !277 - #736: Implemented format() for more scalar types.
- !278 - #737 Misleading error message from the list of floats conversion.
- !279, !280 - #738 CI improvements
- !281 - #611: Updated k.h as of 2016.02.18
- !286, !288, !289, !290 - #742 PyQ Documentation
- !287 - #745: Automatically generate version.py for PyQ during setup.

PyQ 3.7.2

Released on 2015-07-28.

- !270 - #726 Reuse dict converter for OrderedDict.
- !267 - #724 and #723 numpy <> q conversion fixes.
- !266 - #725 Use 001..002 to bracket ANSI escapes.
- !265 - #721 Made slicing work properly with associations (dictionaries) and keyed tables.
- !260 - #719 Backport python 3 bug fixes.
- CI Improvements (!257, !262, !269, !268).

PyQ 3.7.1

Released on 2015-02-12.

- !244 - #701 Fixed using q datetime (z) objects in format().
- !246 - Removed pytest-pyq code. pytest-pyq is now separate package.
- !247 - #709 IPython q-magic improvements
- !248 - #673 Implemented unicode to q symbol conversion in python 2.x.

- !249, !252 - #691 Improved test coverage
- !250, !251 - #695 Use Tox as test-runner
- !253 - #715 Fixed table size computation in getitem.
- !255 - #691 Remove redundant code in slice implementation

PyQ 3.7

Released on 2015-01-15.

- !222 - #581 Implements conversion of record arrays.
- !223 - #680 Fixed int32 conversion bug.
- !224 - #681 Fixed datetime bug - freed memory access.
- !225 - Added support for numpy.int8 conversion.
- !226 - #644 Fixed descriptor protocol.
- !227 - #663 Fixed nil repr (again).
- !228, !233, !237, !239 - #687 Updates to documentation in preparation to public release.
- !229 - #690 Use only major kx version in _k module name.
- !230 - #691 Added tests, fixed date/time list conversion.
- !232 - #693 Implement pyq.magic.
- !234 - #694 Use single source for python 2 and 3. (No 2to3.)
- !235 - #674 Added support for nested lists.
- !236 - #678 Fixed compiler warnings.
- !238 - #657 Make numpy optional.
- !240 - #674 Added support for nested tuples.
- !241 - #696 Implemented slicing of K objects.
- !242 - #699 int and float of non-scalar will raise TypeError.
- !243 - #697 Fixed a datetime bug.

PyQ 3.6.2

Released on 2014-12-23.

- !198 - #654 Restore python 3 compatibility
- !211 - #667 Added pyq.c into MANIFEST
- !213 - #669 Fixed a crash on Mac
- !214 - #590 Implemented numpy date (M8) to q conversion
- !215, !216 - #590 Implemented support for Y, M, W, and D date units
- !217, !218, !220, !221 - #666 Multiple CI improvements
- !219 - #676 Implemented numpy.timedelta64 to q conversion

PyQ 3.6.1

Released on 2014-11-06.

- !206 - #663 Fixed nil repr
- !207 - CI should use cached version of packages
- !208 - #665 Allow K objects to be written into ipython zmq.iostream
- !209 - Show python code coverage in CI
- !210 - #666: Extract C and Python coverage to print in the bottom of the CI run
- !212 - Bump version to 3.6.1b1

PyQ 3.6.0

Released on 2014-10-23.

- !189 - #647 Fix pyq.q() prompt
- !190 - CI should use Python 2.7.8
- !191 - #648 Boolean from empty symbol should be False
- !192 - #634: Moved time converter to C and removed unused converters
- !193 - #652 Added `__long__` method to K type.
- !194 - #653 Allow K integer scalars to be used as indices
- !195, !197 - #651 Format for scalar types D, M, T, U, and V.
- !196 - #611 Updated k.h to 2014.09.11
- !199 - #656 Iteration over K scalars will now raise `TypeError`.
- !200 - #655 Added support for Python 3 in CI
- !202 - #571 Added support for uninstalling Q components
- !203 - #633 Improve test coverage
- !204 - #633 Added boundary and None checks in ja

PyQ 3.5.2

Released on 2014-07-03.

- !184, !186 - #639 taskset support. Use CPUS variable to assign CPU affinity.
- !187 - #641 color prompt
- !185 - #640 Restore minimal support for old buffer protocol

PyQ 3.5.1

Released on 2014-06-27.

- !177, !178 - #631 pyq is binary executable, not script and can be used in hashbang.
- !179 - #633 Added memoryview tests.

- !181 – #636 Moved extension module into pyq package.
- !182 – #633 Removed old buffer protocol support.
- !183 - #638 Calling q() with no arguments produces an emulation of q) prompt

PyQ 3.5.0

Released on 2014-06-20.

- !164 – #611 Updated k.h
- !165 – #614 Expose jv
- !166 – #580 Show with output=str will return string
- !167 – #627 Fixed p language
- !168 – Fix for pip, PyCharm and OS X
- !169 – #629 python.py script was renamed to pyq
- !170 – #632 jv reference leak
- !171 – #633 C code review
- !172 – #634 k new
- !173 – #612 Generate C code coverage for CI
- !174, !175 – #633 test coverage
- !176 – #635 Disable strict aliasing

PyQ 3.4.5

Released on 2014-05-27.

- 614: Expose dj and ktj
- 620: Empty table should be falsy
- 622: Convert datetime to “p”, not “z”

PyQ 3.4.4

Released on 2014-05-23.

- python.q returns correct exit code

PyQ 3.4.3

Released on 2014-04-11.

- 617: Dict Conversion
- 619: Len Keyed Table

PyQ 3.4.2

Released on 2014-04-11.

- 589: Symbol array roundtripping
- 592: Properly register `py.path.local`
- 594: Support passing additional values to `select/update/exec` methods.
- 595: Implement `pytest_pyq` plugin
- 596: Implement python dict converter
- 601: Add support for `^` (fill) operator
- 602: Fix `r`-ops for non-commutative operations.
- 603: Fix unary `+` and implement unary `~`
- 604: Make all `q` methods accessible from `pyq` as attributes
- 609: Updated `k.h` to the latest `kx` version
- NUC: Only true division is supported. Use “`from __future__ import division`” in python 2.x.

PyQ 3.4.1

Released on 2014-03-14.

- Add support for char arrays #588
- PyQ can now be properly installed with `pip -r requirements.txt` #572

PyQ 3.4

Released on 2014-03-07.

- Issues fixed: #582, #583, #584, #586
- Support dictionary/namespace access by `.key`
- Support `ma.array(x)` explicit conversion
- Add support for comparison of `q` scalars

PyQ 3.3

Released on 2014-02-05.

- Issues fixed: #574, #575, #576, #577, #578

PyQ 3.2

Released on 2013-12-24.

- Issues fixed: #556, #559, #560, #561, #562, #564, #565, #566, #569, #570, #573
- **NEW: wrapper for `python.q` to use it under PyCharm** Note: You will need to create symlink from `python` to `python.py` in order for this to work, i.e.: `ln -s bin/python.py bin/python`

- Support to use 32-bit Q under 64-bit OS X

PyQ 3.2.0 beta

- Convert int to KI if KXVER < 3, KJ otherwise
- In Python 2.x convert long to KJ for any KXVER

PyQ 3.1.0

Released on 2012-08-25.

- support Python 3.2
- release pyq-3.1.0 as a source archive

2012-08-10

- basic guid support

PyQ 3.0.1

Released on 2012-08-09.

- support both q 2.x and 3.x
- better setup.py
- release pyq-3.0.1 as a source archive

2009-10-23

- NUC: k3i
- K(None) => k("::")
- K(timedelta) => timespan

2009-01-02

- Use k(0, ..) instead of dot() and aN() to improve compatibility
- Default to python 2.6
- Improvements to q script.p
- NUC: extra info on q errors

2007-03-30

implemented K._ja

0.3

- Added support for arrays of strings

0.2

- Implemented iterator protocol.

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