KDB+

High-Performance Database

tutorialspoint

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About the Tutorial

Kdb+ is a high-performance column-oriented database from **Kx Systems Inc**. kdb+ is designed to capture, analyze, compare, and store data — all at high speeds and on high volumes of data.

The tutorial starts off with a basic introduction of Kdb+ followed by its architecture, installation, and a basic-to-advanced coverage of **q programming language**.

Audience

This reference has been prepared for beginners to help them understand the KDB+ database and write smart queries in **q** languages for KDB+.

Prerequisites

As we are going to start from scratch, you can set off without any preparation. However, it would definitely help if you have a working knowledge of any database or a programming language.

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PART 1: KDB+ ARCHITECTURE

1. OVERVIEW

This is a complete quide to **kdb+** from kx systems, aimed primarily at those learning independently. kdb+, introduced in 2003, is the new generation of the kdb database which is designed to capture, analyze, compare, and store data.

A kdb+ system contains the following two components:

- **KDB+** – the database (k database plus)
- **Q** – the programming language for working with kdb+

Both **kdb+** and **q** are written in **k programming language** (same as **q** but less readable).

Background

Kdb+/q originated as an obscure academic language but over the years, it has gradually improved its user friendliness.

- **APL** (1964, A Programming Language)
- **A+** (1988, modified APL by Arthur Whitney)
- **K** (1993, crisp version of A+, developed by A. Whitney)
- **Kdb** (1998, in-memory column-based db)
- **Kdb+/q** (2003, q language – more readable version of k)

Why and Where to Use KDB+

Why? – If you need a single solution for real-time data with analytics, then you should consider kdb+. Kdb+ stores database as ordinary native files, so it does not have any special needs regarding hardware and storage architecture. It is worth pointing out that the database is just a set of files, so your administrative work won't be difficult.

Where to use KDB+**?** – It's easy to count which investment banks are NOT using kdb+ as most of them are using currently or planning to switch from conventional databases to kdb+. As the volume of data is increasing day by day, we need a system that can handle huge volumes of data. KDB+ fulfills this requirement. KDB+ not only stores an enormous amount of data but also analyzes it in real time.

Getting Started

With this much of background, let us now set forth and learn how to set up an environment for KDB+. We will start with how to download and install KDB+.

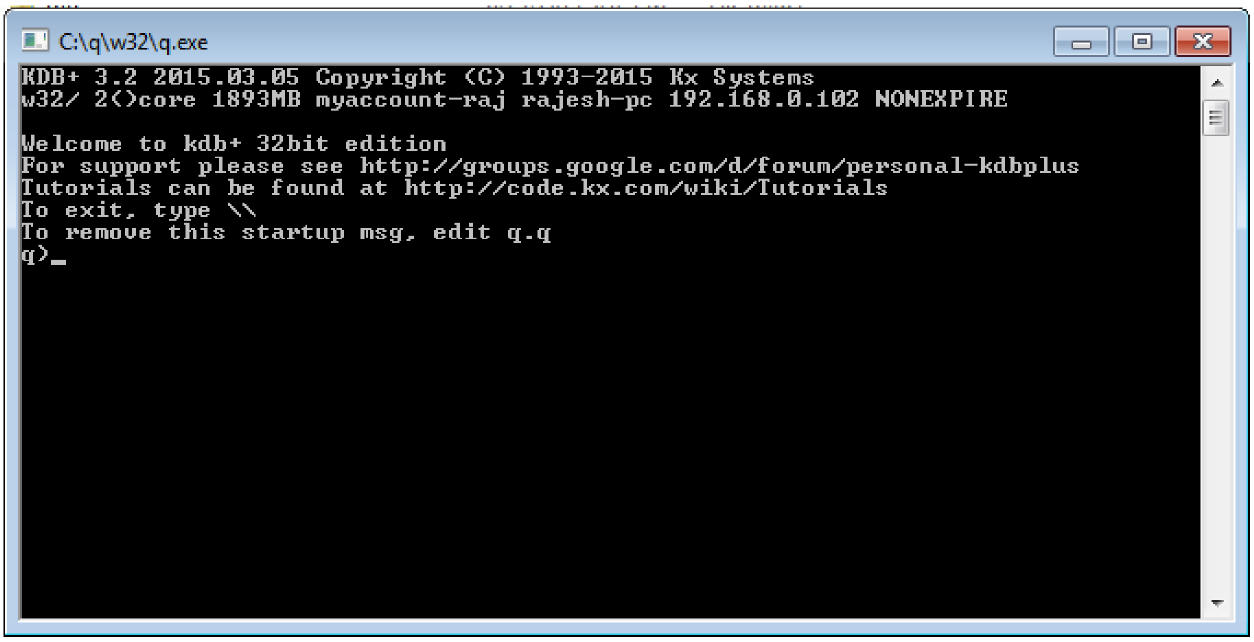
Downloading & Installing KDB+

You can get the free 32-bit version of KDB+, with all the functionality of the 64-bit version from

http://kx.com/software-download.php

Agree to the license agreement, select the operating system (available for all major operating system). For Windows operating system, the latest version is 3.2. Download the latest version. Once you unzip it, you will get the folder name "**windows**" and inside the windows folder, you will get another folder "**q**". Copy the entire **q** folder onto your c:/ drive.

Open the Run terminal, type the location where you store the **q** folder; it will be like "c:/q/w32/q.exe". Once you hit Enter, you will get a new console as follows:



```
KDB+ 3.2 2015.03.05 Copyright (C) 1993-2015 Kx Systems
w32/ 2()core 1893MB myaccount-raj rajesh-pc 192.168.0.102 NONEXPIRE

Welcome to kdb+ 32bit edition
For support please see http://groups.google.com/d/forum/personal-kdbplus
Tutorials can be found at http://code.kx.com/wiki/Tutorials
To exit, type \\
To remove this startup msg, edit q.q
q)_
```

On the first line, you can see the version number which is 3.2 and the release date as 2015.03.05

Directory Layout

The trial/free version is generally installed in directories,

For linux/Mac:

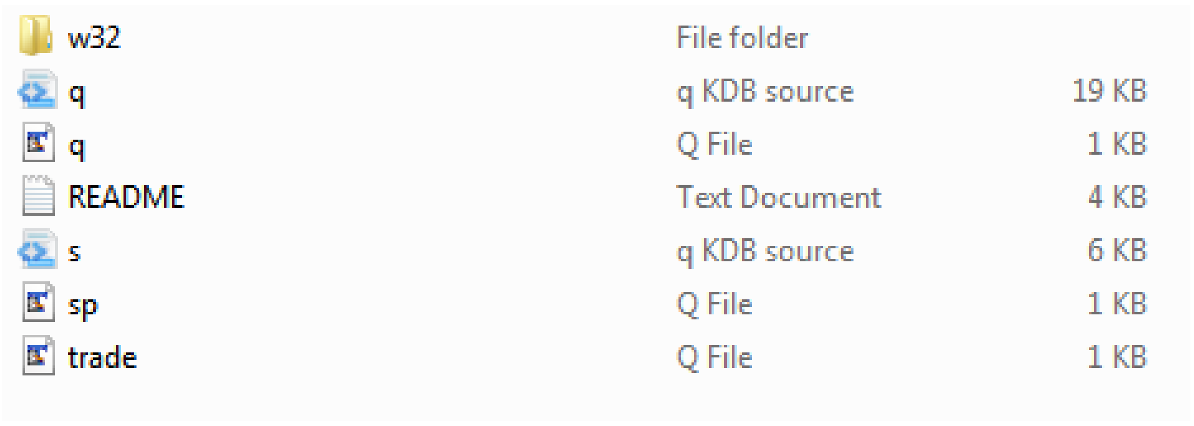
```
~/q                     / main q directory (under the user’s home)
~/q/l32                 / location of linux 32-bit executable
~/q/m32                 / Location of mac 32-bit executable
```

For Windows:

```
c:/q                    / Main q directory
c:/q/w32/               / Location of windows 32-bit executable
```

Example Files:

Once you download kdb+, the directory structure in the Windows platform would appear as follows:



w32	File folder	
q	q KDB source	19 KB
q	Q File	1 KB
README	Text Document	4 KB
s	q KDB source	6 KB
sp	Q File	1 KB
trade	Q File	1 KB

In the above directory structure, **trade.q** and **sp.q** are the example files which we can use as a reference point.

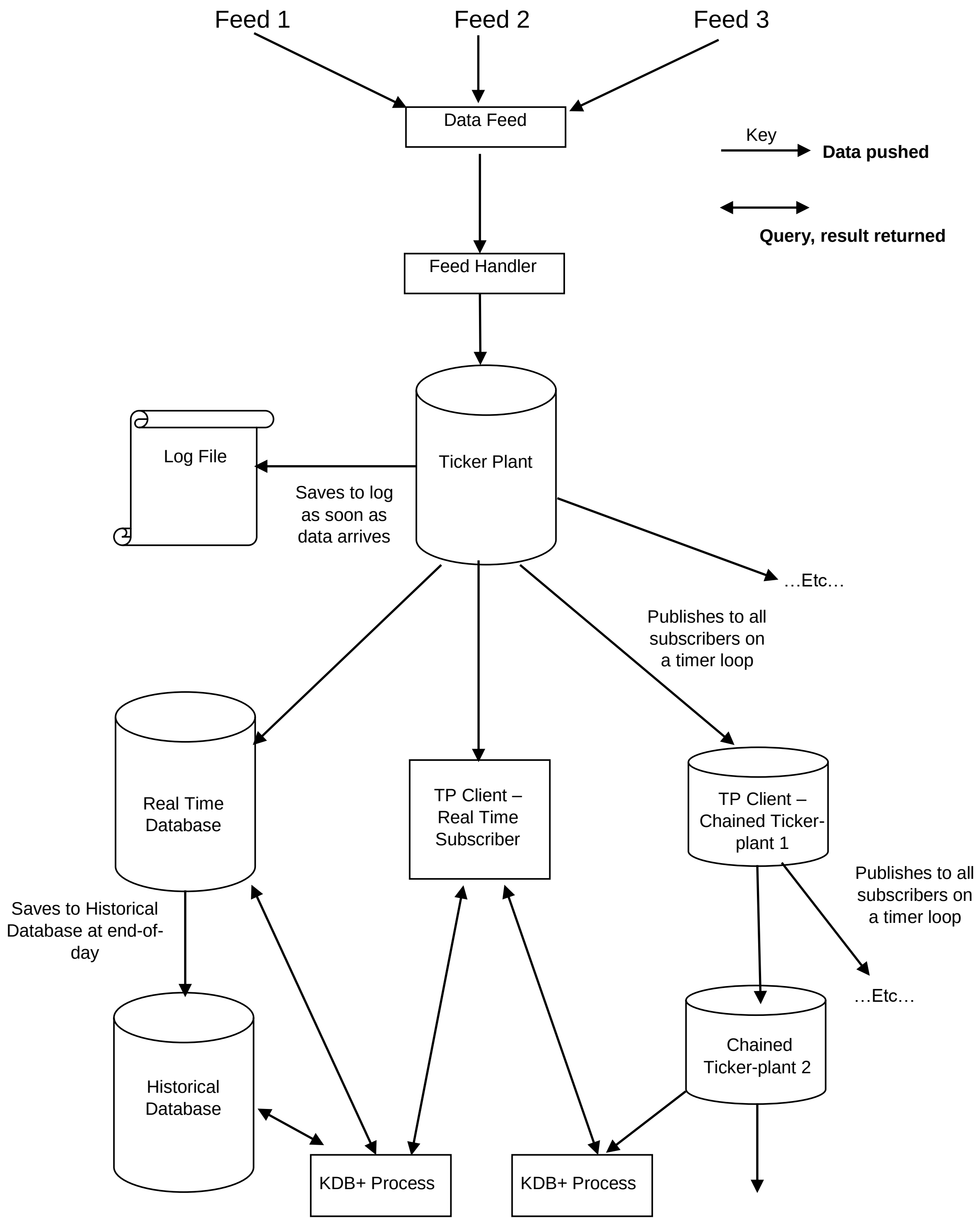
2. KDB+ ARCHITECTURE

Kdb+ is a high-performance, high-volume database designed from the outset to handle tremendous volumes of data. It is fully 64-bit, and has built-in multi-core processing and multi-threading. The same architecture is used for real-time and historical data. The database incorporates its own powerful query language, **q**, so analytics can be run directly on the data.

kdb+tick is an architecture which allows the capture, processing, and querying of real-time and historical data.

Kdb+/ tick Architecture

The following illustration provides a generalized outline of a typical Kdb+/tick architecture, followed by a brief explanation of the various components and the through-flow of data.


Feed 1
Feed 2
Feed 3
Data Feed
Key
Data pushed
Query, result returned
Feed Handler
Log File
Ticker Plant
Saves to log as soon as data arrives
…Etc…
Publishes to all subscribers on a timer loop
Real Time Database
TP Client – Real Time Subscriber
TP Client – Chained Ticker-plant 1
Publishes to all subscribers on a timer loop
Saves to Historical Database at end-of-day
…Etc…
Historical Database
Chained Ticker-plant 2
KDB+ Process
KDB+ Process

- The **Data Feeds** are a time series data that are mostly provided by the data feed providers like Reuters, Bloomberg or directly from exchanges.
- To get the relevant data, the data from the data feed is parsed by the **feed handler**.
- Once the data is parsed by the feed handler, it goes to the **ticker-plant**.
- To recover data from any failure, the ticker-plant first updates/stores the new data to the log file and then updates its own tables.
- After updating the internal tables and the log files, the on-time loop data is continuously sent/published to the real-time database and all the chained subscribers who requested for data.
- At the end of a business day, the log file is deleted, a new one created and the real-time database is saved onto the historical database. Once all the data is saved onto the historical database, the real-time database purges its tables.

Components of Kdb+ Tick Architecture

Data Feeds

Data Feeds can be any market or other time series data. Consider data feeds as the raw input to the feed-handler. Feeds can be directly from the exchange (live-streaming data), from the news/data providers like Thomson-Reuters, Bloomberg, or any other external agencies.

Feed Handler

A feed handler converts the data stream into a format suitable for writing to kdb+. It is connected to the data feed and it retrieves and converts the data from the feed-specific format into a Kdb+ message which is published to the ticker-plant process. Generally a feed handler is used to perform the following operations:

- Capture data according to a set of rules.
- Translate (/enrich) that data from one format to another.
- Catch the most recent values.

Ticker Plant

Ticker Plant is the most important component of KDB+ architecture. It is the ticker plant with which the real-time database or directly subscribers (clients) are connected to access the financial data. It operates in **publish and subscribe** mechanism. Once you obtain a subscription (license), a tick (routinely) publication from the publisher (ticker plant) is defined. It performs the following operations:

- Receives the data from the feed handler.

- Immediately after the ticker plant receives the data, it stores a copy as a log file and updates it once the ticker plant gets any update so that in case of any failure, we should not have any data loss.
- The clients (real-time subscriber) can directly subscribe to the ticker-plant.
- At the end of each business day, i.e., once the real-time database receives the last message, it stores all of today's data onto the historical database and pushes the same to all the subscribers who have subscribed for today's data. Then it resets all its tables. The log file is also deleted once the data is stored in the historical database or other directly linked subscriber to real time database (rtdb).
- As a result, the ticker-plant, the real-time database, and the historical database are operational on a 24/7 basis.

Since the ticker-plant is a Kdb+ application, its tables can be queried using **q** like any other Kdb+ database. All ticker-plant clients should only have access to the database as subscribers.

Real-Time Database

A real-time database (rdb) stores today's data. It is directly connected to the ticker plant. Typically it would be stored in memory during market hours (a day) and written out to the historical database (hdb) at the end of day. As the data (rdb data) is stored in memory, processing is extremely fast.

As kdb+ recommends to have a RAM size that is four or more times the expected size of data per day, the query that runs on rdb is very fast and provides superior performance. Since a real-time database contains only today's data, the date column (parameter) is not required.

For example, we can have rdb queries like,

```
select from trade where sym = `ibm

OR

select from trade where sym = `ibm, price > 100
```

Historical Database

If we have to calculate the estimates of a company, we need to have its historical data available. A historical database (hdb) holds data of transactions done in the past. Each new day's record would be added to the hdb at the end of day. Large tables in the hdb are either stored splayed (each column is stored in its own file) or they are stored partitioned by temporal data. Also some very large databases may be further partitioned using **par.txt** (file).

These storage strategies (splayed, partitioned, etc.) are efficient while searching or accessing the data from a large table.

A historical database can also be used for internal and external reporting purposes, i.e., for analytics. For example, suppose we want to get the company trades of IBM for a particular day from the trade (or any) table name, we need to write a query as follows:

```
thisday: 2014.10.12


select from trade where date= thisday, sym=`ibm
```

Note – We will write all such queries once we get some overview of the **q** language.

PART 2: Q PROGRAMMING LANGUAGE

3. Q PROGRAMMING LANGUAGE

Kdb+ comes with its built-in programming language that is known as **q**. It incorporates a superset of standard SQL which is extended for time-series analysis and offers many advantages over the standard version. Anyone familiar with SQL can learn **q** in a matter of days and be able to quickly write her own ad-hoc queries.

Starting the "q" Environment

To start using kdb+, you need to start the **q** session. There are three ways to start a **q** session:

- Simply type "c:/q/w32/q.exe" on your run terminal.
- Start the MS-DOS command terminal and type **q**.
- Copy the **q.exe** file onto "C:\Windows\System32" and on the run terminal, just type "q".

Here we are assuming that you are working on a Windows platform.

Data Types

The following table provides a list of supported data types:

Name	Example	Char	Type	Size
boolean	1b	b	1	1
byte	0xff	x	4	1
short	23h	h	5	2
int	23i	i	6	4
long	23j	j	7	8
real	2.3e	e	8	4
float	2.3f	f	9	8
char	"a"	c	10	1
varchar	`ab	s	11	*
month	2003.03m	m	13	4
date	2015.03.17T18:01:40.134	z	15	8

minute	08:31	u	17	4
second	08:31:53	v	18	4
time	18:03:18.521	t	19	4
enum	\`u$\`b, where u:\`a\`b	*	20	4

Atom and List Formation

Atoms are single entities, e.g., a single number, a character or a symbol. In the above table (of different data types), all supported data types are atoms. A list is a sequence of atoms or other types including lists.

Passing an atom of any type to the monadic (i.e. single argument function) type function will return a negative value, i.e., **–n**, whereas passing a simple list of those atoms to the type function will return a positive value **n**.

Example 1 – Atom and List Formation

```
/ Note that the comments begin with a slash “ / ” and cause the parser
/ to ignore everything up to the end of the line.


x: `mohan                    / `mohan is a symbol, assigned to a
variable x
type x                       / let’s check the type of x
-11h                         / -ve sign, because it’s single element.
y: (`abc;`bca;`cab)          / list of three symbols, y is the variable
name.
type y
11h                    / +ve sign, as it contain list of atoms (symbol).
y1: (`abc`bca`cab)           / another way of writing y, please note NO
semicolon
y2: (`$”symbols may have interior blanks”)      / string to symbol
conversion
y[0]                         / return `abc
y 0                          / same as y[0], also returns `abc
y 0 2                        / returns `abc`cab, same as does y[0 2]
z: (`abc; 10 20 30; (`a`b); 9.9 8.8 7.7)      / List of different
types,
z 2 0                        / returns (`a`b; `abc),
z[2;0]                       / return `a. first element of z[2]
```

```
x: “Hello World!”             / list of character, a string
x 4 0                         / returns “oH” i.e. 4th and 0th(first)
element
```

4. TYPE CASTING

It is often required to change the data type of some data from one type to another. The standard casting function is the "$" **dyadic operator**.

Three approaches are used to cast from one type to another (except for string):

1. Specify desired data type by its symbol name
2. Specify desired data type by its character
3. Specify desired data type by it short value.

Casting Integers to Floats

In the following example of casting integers to floats, all the three different ways of casting are equivalent:

```
q)a:9 18 27
q)$[`float;a]    / Specify desired data type by its symbol name, 1st way
9 18 27f
q)$["f";a]       / Specify desired data type by its character, 2nd way
9 18 27f
q)$[9h;a]        / Specify desired data type by its short value, 3rd way
9 18 27f
```

Check if all the three operations are equivalent,

```
q)($[`float;a]~$["f";a]) and ($[`float;a] ~ $[9h;a])
1b
```

Casting Strings to Symbols

Casting string to symbols and vice versa works a bit differently. Let's check it with an example:

```
q)b: ("Hello";"World";"HelloWorld")      / define a list of strings
q)b
"Hello"
"World"
```

```
"HelloWorld"
q)c: `$b                     / this is how to cast strings to symbols
q)c                          / Now c is a list of symbols
`Hello`World`HelloWorld
```

Attempting to cast strings to symbols using the keyed words `symbol or 11h will fail with the type error:

```
q)b
"Hello"
"World"
"HelloWorld"
q)`symbol$b
'type
q)11h$b
'type
```

Casting Strings to Non-Symbols

Casting strings to a data type other than symbol is accomplished as follows:

```
q)b:900                 / b contain single atomic integer
q)c:string b            / convert this integer atom to string “900”
q)c
"900"
q)`int $ c              / converting string to integer will return the
                        / ASCII equivalent of the character “9”, “0” and
                        / “0” to produce the list of integer 57, 48 and
                        / 48.
57 48 48i
q)6h $ c                / Same as above
57 48 48i
q)"i" $ c               / Same a above
57 48 48i
q)"I" $ c
900i
```

So to cast an entire string (the list of characters) to a single atom of data type **x** requires us to specify the upper case letter representing data type **x** as the first argument to the **$** operator. If you specify the data type of **x** in any other way, it result in the cast being applied to each character of the string.

5. TEMPORAL DATA

The **q** language has many different ways of representing and manipulating temporal data such as times and dates.

Date

A date in kdb+ is internally stored as the integer number of days since our reference date is 01Jan2000. A date after this date is internally stored as a positive number and a date before that is referenced as a negative number.

By default, a date is written in the format "YYYY.MM.DD"

```
q)x:2015.01.22   / This is how we write 22nd Jan 2015
q)`int$x         / Number of days since 2000.01.01
5500i
q)`year$x        / Extracting year from the date
2015i
q)x.year         / Another way of extracting year
2015i
q)`mm$x          / Extracting month from the date
1i
q)x.mm           / Another way of extracting month
1i
q)`dd$x          / Extracting day from the date
22i
q)x.dd           / Another way of extracting day
22i
```

Arithmetic and logical operations can be performed directly on dates.

```
q)x+1                  / Add one day
2015.01.23
q)x-7                  / Subtract 7 days
2015.01.15
```

The 1st of January 2000 fell on a Saturday. Therefore any Saturday throughout the history or in the future when divided by 7, would yield a remainder of 0, Sunday gives 1, Monday yield 2.

Day	mod 7
Saturday	0
Sunday	1
Monday	2
Tuesday	3
Wednesday	4
Thursday	5
Friday	6

Times

A time is internally stored as the integer number of milliseconds since the stroke of midnight. A time is written in the format HH:MM:SS.MSS

```
q)tt1: 03:30:00.000    / tt1 store the time 03:30 AM

q)tt1

03:30:00.000

q)`int$tt1             / Number of milliseconds in 3.5 hours

12600000i

q)`hh$tt1              /  Extract the hour component from time

3i

q)tt1.hh

3i

q)`mm$tt1              / Extract the minute component from time

30i

q)tt1.mm

30i

q)`ss$tt1              / Extract the second component from time

0i

q)tt1.ss

0i
```

As in case of dates, arithmetic can be performed directly on times.

Datetimes

A datetime is the combination of a date and a time, separated by 'T' as in the ISO standard format. A datetime value stores the fractional day count from midnight Jan 1, 2000.

```
q)dt:2012.12.20T04:54:59:000      / 04:54.59 AM on 20thDec2012
q)type dt
-15h
q)dt
2012.12.20T04:54:59.000
q)`float$dt
4737.205
```

The underlying fractional day count can be obtained by casting to float.

6. LISTS

Lists are the basic building blocks of **q language**, so a thorough understanding of lists is very important. A list is simply an ordered collection of atoms (atomic elements) and other lists (group of one or more atoms).

Types of List

A **general list** encloses its items within matching parentheses and separates them with semicolons. For example:

```
(9;8;7)    or     ("a"; "b"; "c")   or   (-10.0; 3.1415e; `abcd; "r")
```

If a list comprises of atoms of same type, it is known as a **uniform list**. Else, it is known as a **general list** (mixed type).

Count

We can obtain the number of items in a list through its count.

```
q)l1:(-10.0;3.1415e;`abcd;"r") / Assigning variable name to general list
q)count l1              / Calculating number of items in the list l1
4
```

Examples of simple List

```
q)h:(1h;2h;255h)                    / Simple Integer List
q)h
1 2 255h
q)f:(123.4567;9876.543;98.7)        / Simple Floating Point List
q)f
123.4567 9876.543 98.7
q)b:(0b;1b;0b;1b;1b)                / Simple Binary Lists
q)b
01011b
q)symbols:(`Life;`Is;`Beautiful)   / Simple Symbols List
q)symbols
`Life`Is`Beautiful
q)chars:("h";"e";"l";"l";"o";" ";"w";"o";"r";"l";"d")
```

```
                                   / Simple char lists and Strings.
q)chars
"hello world"
```

****Note: A simple list of char is called a string.**

A list contains atoms or lists. **To create a single item list**, we use:

```
q)singleton:enlist 42
q)singleton
,42
```

To distinguish between an atom and the equivalent singleton, examine the sign of their type.

```
q)signum type 42
-1i
q)signum type enlist 42
1i
```

7. INDEXING

A list is ordered from left to right by the position of its items. The offset of an item from the beginning of the list is called its **index**. Thus, the first item has an index 0, the second item (if there is one) has an index 1, etc. A list of count **n** has index domain from **0** to **n–1**.

Index Notation

Given a list `L`, the item at index `i` is accessed by `L[i]`. Retrieving an item by its index is called **item indexing**. For example,

```
q)L:(99;98.7e;`b;`abc;"z")
q)L[0]
99
q)L[1]
98.7e
q)L[4]
"z"
```

Indexed Assignment

Items in a list can also be assigned via item indexing. Thus,

```
q)L1:9 8 7
q)L1[2]:66       / Indexed assignment into a simple list
                 / enforces strict type matching.
q)L1
9 8 66
```

Lists from Variables

```
q)l1:(9;8;40;200)
q)l2:(1 4 3; `abc`xyz)
q)l:(l1;l2)            / combining the two list l1 and l2
q)l
9 8 40 200
```

```
(1 4 3;`abc`xyz)
```

Joining Lists

The most common operation on two lists is to join them together to form a larger list. More precisely, the join operator (,) appends its right operand to the end of the left operand and returns the result. It accepts an atom in either argument.

```
q)1,2 3 4
1 2 3 4
q)1 2 3, 4.4 5.6       / If the  arguments are not of uniform type,
                       / the result is a general list.
1
2
3
4.4
5.6
```

Nesting

Data complexity is built by using lists as items of lists

Depth

The number of levels of nesting for a list is called its depth. Atoms have a depth of 0 and simple lists have a depth of 1.

```
q)l1:(9;8;(99;88))
q)count l1
3
```

Here is a list of depth 3 having two items:

```
q)l5
9
(90;180;900 1800 2700 3600)
q)count l5
2
q)count l5[1]
3
```

Indexing at Depth

It is possible to index directly into the items of a nested list.

Repeated Item Indexing

Retrieving an item via a single index always retrieves an uppermost item from a nested list.

```
q)L:(1;(100;200;(300;400;500;600)))
q)L[0]
1
q)L[1]
100
200
300 400 500 600
```

Since the result **L[1]** is itself a list, we can retrieve its elements using a single index.

```
q)L[1][2]
300 400 500 600
```

We can repeat single indexing once more to retrieve an item from the innermost nested list.

```
q)L[1][2][0]
300
```

You can read this as,

> *Get the item at index 1 from L, and from it retrieve the item at index 2, and from it retrieve the item at index 0.*

Notation for Indexing at Depth

There is an alternate notation for repeated indexing into the constituents of a nested list. The last retrieval can also be written as,

```
q)L[1;2;0]
300
```

Assignment via index also works at depth.

```
q)L[1;2;1]:900
q)L
1
(100;200;300 900 500 600)
```

Elided Indices

Eliding Indices for a General List

```
q)L:((1 2 3; 4 5 6 7); (`a`b`c;`d`e`f`g;`0`1`2);("good";"morning"))
q)L
(1 2 3;4 5 6 7)
(`a`b`c;`d`e`f`g;`0`1`2)
("good";"morning")
q)L[;1;]
4 5 6 7
`d`e`f`g
"morning"
q)L[;;2]
3 6
`c`f`2
"or"
```

Interpret L[;1;] as,

Retrieve all items in the second position of each list at the top level.

Interpret L[;;2] as,

Retrieve the items in the third position for each list at the second level.

8. DICTIONARIES

Dictionaries are an extension of lists which provide the foundation for creating tables. In mathematical terms, dictionary creates the

“domain ➔ Range”

or in general (short) creates

“key ➔ value”

relationship between elements.

A dictionary is an ordered collection of key-value pairs that is roughly equivalent to a hash table. A dictionary is a mapping defined by an explicit I/O association between a domain list and a range list via positional correspondence. The creation of a dictionary uses the "xkey" primitive (!)

```
ListOfDomain  !  ListOfRange
```

The most basic dictionary maps a simple list to a simple list.

Input (I)	Output (O)
`Name	`John
`Age	36
`Sex	“M”
Weight	60.3

```
q)d:`Name`Age`Sex`Weight!(`John;36;"M";60.3)   / Create a dictionary d
q)d
Name  | `John
Age   | 36
Sex   | "M"
Weight| 60.3
q)count d                / To get the number of rows in a dictionary.
4
q)key d                  / The function key returns the domain
`Name`Age`Sex`Weight
q)value d                / The function value returns the range.
```

```
`John
36
"M"
60.3
q)cols d               / The function cols also returns the domain.
`Name`Age`Sex`Weight
```

Lookup

Finding the dictionary output value corresponding to an input value is called **looking up** the input.

```
q)d[`Name]             / Accessing the value of domain `Name
`John
q)d[`Name`Sex]         /  extended item-wise to a simple list of keys
`John
"M"
```

Lookup with Verb @

```
q)d1:`one`two`three!9 18 27
q)d1[`two]
18
q)d1@`two
18
```

Operations on Dictionaries

Amend and Upsert

As with lists, the items of a dictionary can be modified via indexed assignment.

```
d:`Name`Age`Sex`Weight! (`John;36;"M";60.3)
                                   / A dictionary d
q)d[`Age]:35                       / Assigning new value to key Age
q)d                                / New value assigned to key Age in d
Name  | `John
Age   | 35
```

```
Sex   | "M"
Weight| 60.3
```

Dictionaries can be extended via index assignment.

```
q)d[`Height]:"182 Ft"
q)d
Name  | `John
Age   | 35
Sex   | "M"
Weight| 60.3
Height| "182 Ft"
```

Reverse Lookup with Find (?)

The find (?) operator is used to perform reverse lookup by mapping a range of elements to its domain element.

```
q)d2:`x`y`z!99 88 77
q)d2?77
`z
```

In case the elements of a list is not unique, the **find** returns the first item mapping to it from the domain list.

Removing Entries

To remove an entry from a dictionary, the **delete** (_) **function** is used. The left operand of (_) is the dictionary and the right operand is a key value.

```
q)d2:`x`y`z!99 88 77
q)d2 _`z
x| 99
y| 88
```

Whitespace is required to the left of _ if the first operand is a variable.

```
q)`x`y _ d2                  / Deleting multiple entries
z| 77
```

Column Dictionaries

Column dictionaries are the basics for creation of tables. Consider the following example:

```
q)scores: `name`id!(`John`Jenny`Jonathan;9 18 27)
                             / Dictionary scores
q)scores[`name]              / The values for the name column are
`John`Jenny`Jonathan
q)scores.name                / Retrieving the values for a column in a
                             / column dictionary using dot notation.
`John`Jenny`Jonathan
q)scores[`name][1]           / Values in row 1 of the name column
`Jenny
q)scores[`id][2]             / Values in row 2 of the id column is
27
```

Flipping a Dictionary

The net effect of flipping a column dictionary is simply reversing the order of the indices. This is logically equivalent to transposing the rows and columns.

Flip on a Column Dictionary

The transpose of a dictionary is obtained by applying the unary flip operator. Take a look at the following example:

```
q)scores
name| John Jenny Jonathan
id  | 9    18    27
q)flip scores
name     id
-----------
John     9
Jenny    18
Jonathan 27
```

Flip of a Flipped Column Dictionary

If you transpose a dictionary twice, you obtain the original dictionary,

```
q)scores ~ flip flip scores

1b
```

9. TABLE

Tables are at the heart of kdb+. A table is a collection of named columns implemented as a dictionary. **q tables** are column-oriented.

Creating Tables

Tables are created using the following syntax:

```
q)trade:([]time:();sym:();price:();size:())
q)trade
time sym price size
-------------------
```

In the above example, we have not specified the type of each column. This will be set by the first insert into the table.

Another way, we can specify column type on initialization:

```
q)trade:([]time:`time$();sym:`$();price:`float$();size:`int$())
```

Or we can also define non-empty tables:

```
q)trade:([]sym:(`a`b);price:(1 2))
q)trade
sym price
---------
a   1
b   2
```

If there are no columns within the square brackets as in the examples above, the table is **unkeyed**.

To create a **keyed table**, we insert the column(s) for the key in the square brackets.

```
q)trade:([sym:`$()]time:`time$();price:`float$();size:`int$())

q)trade

sym| time price size

---| ---------------
```

One can also define the column types by setting the values to be null lists of various types:

```
q)trade:([]time:0#0Nt;sym:0#`;price:0#0n;size:0#0N)
```

Getting Table Information

Let's create a trade table:

```
trade: ([]sym:`ibm`msft`apple`samsung;mcap:2000 4000 9000
6000;ex:`nasdaq`nasdaq`DAX`Dow)

q)cols trade                          / column names of a table

`sym`mcap`ex

q)trade.sym                           / Retrieves the value of column sym

`ibm`msft`apple`samsung

q)show meta trade                     / Get the meta data of a table trade.

c    |    t    f    a

----  | -----

Sym  |     s

Mcap|      j

ex   |     s
```

Primary Keys and Keyed Tables

Keyed Table

A keyed table is a dictionary that maps each row in a table of unique keys to a corresponding row in a table of values. Let us take an example:

```
val:flip `name`id!(`John`Jenny`Jonathan;9 18 27)

                           / a flip dictionary create table val

id:flip (enlist `eid)!enlist 99 198 297

                           / flip dictionary, having single column eid
```

Now create a simple keyed table containing eid as key,

```
q)valid: id ! val

q)valid                      / table name valid, having key as eid

eid| name     id

---| -----------

99 | John     9

198| Jenny    18

297| Jonathan 27
```

Foreign Keys

A **foreign key** defines a mapping from the rows of the table in which it is defined to the rows of the table with the corresponding **primary key**.

Foreign keys provide **referential integrity**. In other words, an attempt to insert a foreign key value that is not in the primary key will fail.

Consider the following examples. In the first example, we will define a foreign key explicitly on initialization. In the second example, we will use foreign key chasing which does not assume any prior relationship between the two tables.

Example 1: Define foreign key on initialization

```
q)sector:([sym:`SAMSUNG`HSBC`JPMC`APPLE]ex:`N`CME`DAQ`N;MC:1000 2000
3000 4000)

q)tab:([]sym:`sector$`HSBC`APPLE`APPLE`APPLE`HSBC`JPMC;price:6?9f)

q)show meta tab

c    | t f      a

-----| ----------
```

```
sym  | s sector
price| f
q)show select from tab where sym.ex=`N
sym   price
--------------
APPLE 4.65382
APPLE 4.643817
APPLE 3.659978
```

Example 2: no pre-defined relationship between tables

```
sector: ([symb:`IBM`MSFT`HSBC]ex:`N`CME`N;MC:1000 2000 3000)
tab:([]sym:`IBM`MSFT`MSFT`HSBC`HSBC;price:5?9f)
```

To use foreign key chasing, we must create a table to key into sector.

```
q)show update mc:(sector([]symb:sym))[`MC] from tab
sym  price    mc
------------------
IBM  7.065297 1000
MSFT 4.812387 2000
MSFT 6.400545 2000
HSBC 3.704373 3000
HSBC 4.438651 3000
```

General notation for a predefined foreign key:

select a.b from c *where a is the foreign key (sym), b is a field in the primary key table (ind), c is the foreign key table (trade)*

Manipulating Tables

Let's create one trade table and check the result of different table expression:

```
q)trade:([]sym:5?`ibm`msft`hsbc`samsung;price:5?(303.00*3+1);size:5?(900
*5);time:5?(.z.T-365))
q)trade
sym     price    size time
```

```
----------------------------------

msft    743.8592 3162 02:32:17.036

msft    641.7307 2917 01:44:56.936

hsbc    838.2311 1492 00:25:23.210

samsung 278.3498 1983 00:29:38.945

ibm     838.6471 4006 07:24:26.842
```

Let us now take a look at the statements that are used to manipulate tables using **q** language.

Select

The syntax to use a **Select** statement is as follows:

```
select [columns] [by columns] from table [where clause]
```

Let us now take an example to demonstrate how to use Select statement:

```
q)/ select expression example

q)select sym,price,size by time from trade where size>2000

time        | sym  price    size

------------| ------------------

01:44:56.936| msft 641.7307 2917

02:32:17.036| msft 743.8592 3162

07:24:26.842| ibm  838.6471 4006
```

Insert

The syntax to use an **Insert** statement is as follows:

```
`tablename insert (values)

Insert[`tablename; values]
```

Let us now take an example to demonstrate how to use Insert statement:

```
q)/ Insert expression example

q)`trade insert (`hsbc`apple;302.0 730.40;3020 3012;09:30:17.004
09:15:00.000)

5 6

q)trade
```

```
sym     price    size time
----------------------------------
msft    743.8592 3162 02:32:17.036
msft    641.7307 2917 01:44:56.936
hsbc    838.2311 1492 00:25:23.210
samsung 278.3498 1983 00:29:38.945
ibm     838.6471 4006 07:24:26.842
hsbc    302      3020 09:30:17.004
apple   730.4    3012 09:15:00.000
q)/Insert another value
q)insert[`trade;(`samsung;302.0; 3333;10:30:00.000]
']
q)insert[`trade;(`samsung;302.0; 3333;10:30:00.000)]
,7
q)trade
sym     price    size time
----------------------------------
msft    743.8592 3162 02:32:17.036
msft    641.7307 2917 01:44:56.936
hsbc    838.2311 1492 00:25:23.210
samsung 278.3498 1983 00:29:38.945
ibm     838.6471 4006 07:24:26.842
hsbc    302      3020 09:30:17.004
apple   730.4    3012 09:15:00.000
samsung 302      3333 10:30:00.000
```

Delete

The syntax to use a **Delete** statement is as follows:

```
delete columns from table
delete from table where clause
```

Let us now take an example to demonstrate how to use Delete statement:

```
q)/Delete expression example
q)delete price from trade
sym     size time
-------------------------
msft    3162 02:32:17.036
msft    2917 01:44:56.936
hsbc    1492 00:25:23.210
samsung 1983 00:29:38.945
ibm     4006 07:24:26.842
hsbc    3020 09:30:17.004
apple   3012 09:15:00.000
samsung 3333 10:30:00.000
q)delete from trade where price > 3000
sym     price    size time
----------------------------------
msft    743.8592 3162 02:32:17.036
msft    641.7307 2917 01:44:56.936
hsbc    838.2311 1492 00:25:23.210
samsung 278.3498 1983 00:29:38.945
ibm     838.6471 4006 07:24:26.842
hsbc    302      3020 09:30:17.004
apple   730.4    3012 09:15:00.000
samsung 302      3333 10:30:00.000
q)delete from trade where price > 500
sym     price    size time
----------------------------------
samsung 278.3498 1983 00:29:38.945
hsbc    302      3020 09:30:17.004
samsung 302      3333 10:30:00.000
```

Update

The syntax to use an **Update** statement is as follows:

```
update column: newValue from table where ….
```

Use the following syntax to update the format/datatype of a column using the cast function:

```
update column:newValue from `table where …
```

Let us now take an example to demonstrate how to use **Update** statement:

```
q)/Update expression example
q)update size:9000 from trade where price>600
sym     price    size time
----------------------------------
msft    743.8592 9000 02:32:17.036
msft    641.7307 9000 01:44:56.936
hsbc    838.2311 9000 00:25:23.210
samsung 278.3498 1983 00:29:38.945
ibm     838.6471 9000 07:24:26.842
hsbc    302      3020 09:30:17.004
apple   730.4    9000 09:15:00.000
samsung 302      3333 10:30:00.000
q)/Update the datatype of a column using the cast function
q)meta trade
c    | t f a
-----| -----
sym  | s
price| f
size | j
time | t
q)update size:`float$size from trade
sym     price    size time
----------------------------------
msft    743.8592 3162 02:32:17.036
msft    641.7307 2917 01:44:56.936
hsbc    838.2311 1492 00:25:23.210
```

```
samsung 278.3498 1983 00:29:38.945
ibm     838.6471 4006 07:24:26.842
hsbc    302      3020 09:30:17.004
apple   730.4    3012 09:15:00.000
samsung 302      3333 10:30:00.000
q)/ Above statement will not update the size column datatype permanently
q)meta trade
c    | t f a
-----| -----
sym  | s
price| f
size | j
time | t
q)/to make changes in the trade table permanently, we have do
q)update size:`float$size from `trade
`trade
q)meta trade
c    | t f a
-----| -----
sym  | s
price| f
size | f
time | t
```

10. VERB & ADVERBS

Kdb+ has nouns, verbs, and adverbs. All data objects and functions are **nouns**. **Verbs** enhance the readability by reducing the number of square brackets and parentheses in expressions. **Adverbs** modify dyadic (2 arguments) functions and verbs to produce new, related verbs. The functions produced by adverbs are called **derived functions** or **derived verb**s.

Each

The adverb **each**, denoted by (‛), modifies dyadic functions and verbs to apply to the items of lists instead of the lists themselves. Take a look at the following example:

```
q)1, (2 3 5)          / Join
1 2 3 5
q)1, '( 2 3 4)        / Join each
1 2
1 3
1 4
```

There is a form of E**ach** for monadic functions that uses the keyword "each". For example,

```
q)reverse ( 1 2 3; "abc")          /Reverse
a b c
1 2 3
q)each [reverse] (1 2 3; "abc")    /Reverse-Each
3 2 1
c b a
q)'[reverse] ( 1 2 3; "abc")
3 2 1
c b a
```

Each-Left and Each-Right

There are two variants of Each for dyadic functions called **Each-Left** (\:) and **Each-Right** (/:). The following example explains how to use them.

```
q)x: 9 18 27 36
q)y:10 20 30 40
q)x,y           / join
9 18 27 36 10 20 30 40
q)x,'y          / each
9  10
18 20
27 30
36 40
q)x: 9 18 27 36
q)y:10 20 30 40
q)x,y           / join
9 18 27 36 10 20 30 40
q)x,'y          / each, will return a list of pairs
9  10
18 20
27 30
36 40
q)x, \:y        / each left, returns a list of each element
                / from x with all of y

9  10 20 30 40
18 10 20 30 40
27 10 20 30 40
36 10 20 30 40
q)x,/:y                / each right, returns a list of all the x with
                       / each element of y
9 18 27 36 10
9 18 27 36 20
9 18 27 36 30
9 18 27 36 40
```

```
q)1 _x                      / drop the first element
18 27 36
q)-2_y                      / drop the last two element
10 20
q)                          / Combine each left and each right to be a
                            / cross-product (cartesian product)
q)x,/:\:y
9 10  9 20  9 30  9 40
18 10 18 20 18 30 18 40
27 10 27 20 27 30 27 40
36 10 36 20 36 30 36 40
```

11. JOINS

In **q** language, we have different kinds of joins based on the input tables supplied and the kind of joined tables we desire. A join combines data from two tables. Besides foreign key chasing, there are four other ways to join tables:

- Simple join
- Asof join
- Left join
- Union join

Here, in this chapter, we will discuss each of these joins in detail.

Simple Join

Simple join is the most basic type of join, performed with a comma ‘,’. In this case, the two tables have to be **type conformant**, i.e., both the tables have the same number of columns in the same order, and same key.

```
    table1,:table2    / table1 is assigned the value of table2
```

We can use comma-each join for tables with same length to join sideways. One of the tables can be keyed here,

```
    Table1, `Table2
```

Asof Join (aj)

It is the most powerful join which is used to get the value of a field in one table asof the time in another table. Generally it is used to get the prevailing bid and ask at the time of each trade.

General format

```
    aj[joinColumns;tbl1;tbl2]
```

For example,

```
aj[`sym`time;trade;quote]
```

Example

```
q)tab1:([]a:(1 2 3 4);b:(2 3 4 5);d:(6 7 8 9))
q)tab2:([]a:(2 3 4);b:(3 4 5); c:( 4 5 6))
q)show aj[`a`b;tab1;tab2]
a b d c
-------
1 2 6
2 3 7 4
3 4 8 5
4 5 9 6
```

Left Join (lj)

It’s a special case of aj where the second argument is a keyed table and the first argument contains the columns of the right argument’s key.

General format

```
          table1 lj Keyed-table
```

Example

```
q)/Left join- syntax table1 lj table2 or lj[table1;table2]
q)tab1:([]a:(1 2 3 4);b:(2 3 4 5);d:(6 7 8 9))
q)tab2:([a:(2 3 4);b:(3 4 5)]; c:( 4 5 6))
q)show lj[tab1;tab2]
a b d c
-------
1 2 6
2 3 7 4
3 4 8 5
4 5 9 6
```

Union Join (uj)

It allows to create a union of two tables with distinct schemas. It is basically an extension to the simple join (,)

```
q)tab1:([]a:(1 2 3 4);b:(2 3 4 5);d:(6 7 8 9))

q)tab2:([]a:(2 3 4);b:(3 4 5); c:( 4 5 6))

q)show uj[tab1;tab2]

a b d c

-------

1 2 6

2 3 7

3 4 8

4 5 9

2 3   4

3 4   5

4 5   6
```

If you are using uj on keyed tables, then the primary keys must match.

12. FUNCTIONS

Types of Functions

Functions can be classified in a number of ways. Here we have classified them based on the number and type of argument they take and the result type. Functions can be,

- **Atomic** – Where the arguments are atomic and produce atomic results
- **Aggregate** – atom from list
- **Uniform (list from list)** – Extended the concept of atom as they apply to lists. The count of the argument list equals the count of the result list.
- **Other** – if the function is not from the above category.

Binary operations in mathematics are called **dyadic functions** in q; for example, "+". Similarly unary operations are called **monadic functions**; for example, "abs" or "floor".

Frequently Used Functions

There are quite a few functions used frequently in **q** programming. Here, in this section, we will see the usage of some popular functions:

abs

```
q) abs -9.9      / Absolute value, Negates -ve number & leaves non -ve number
9.9
```

all

```
q) all 4 5 0 -4  / Logical AND (numeric min), returns the minimum value
0b
```

Max (&), Min (|), and Not (!)

```
q)   /And, Or, and Logical Negation
q) 1b & 1b       / And (Max)
1b
q) 1b|0b         / Or (Min)
```

```
1b
q) not 1b        /Logical Negate (Not)
0b
```

asc

```
q)asc 1 3 5 7 -2 0 4    / Order list ascending, sorted list
                        / in ascending order i
s returned
`s#-2 0 1 3 4 5 7
q)/attr - gives the attributes of data, which describe how it's sorted.
`s denotes fully sorted, `u denotes unique and `p and `g are used to
refer to lists with repetition, with `p standing for parted and `g for
grouped
```

avg

```
q)avg 3 4 5 6 7         / Return average of a list of numeric values
5f
q)/Create on trade table
q)trade:([]time:3?(.z.Z-
200);sym:3?(`ibm`msft`apple);price:3?99.0;size:3?100)
```

by

```
q)/ by - Groups rows in a table at given sym
q)select sum price by sym from trade    / find total price for each sym
sym  | price
-----| --------
apple| 140.2165
ibm  | 16.11385
```

cols

```
q)cols trade    / Lists columns of a table
`time`sym`price`size
```

count

```
q)count (til 9)  / Count list, count the elements in a list and
                 / return a single int value 9
```

port

```
q)\p 9999  / assign port number

q)/csv -  This command allows queries in a browser to be exported to
excel by prefixing the query, such as http://localhost:9999/.csv?select
from trade where sym=`ibm
```

cut

```
q)/ cut - Allows a table or list to be cut at a certain point

q)(1 3 5) cut "abcdefghijkl"

                  / the argument is split at 1st, 3rd and 5th letter.

"bc"

"de"

"fghijkl"

q)5 cut "abcdefghijkl"      / cut the right arg. Into 5 letters part
                            / until its end.

"abcde"

"fghij"

"kl"
```

Delete

```
q)/delete -     Delete rows/columns from a table

q)delete price from trade

time                    sym   size

----------------------------------

2009.06.18T06:04:42.919 apple 36

2009.11.14T12:42:34.653 ibm   12

2009.12.27T17:02:11.518 apple 97
```

Distinct

```
q)/distinct - Returns the distinct element of a list
q)distinct 1 2 3 2 3 4 5 2 1 3          / generate unique set of number
1 2 3 4 5
```

enlist

```
q)/enlist - Creates one-item list.
q)enlist 37
,37
q)type 37              / -ve type value
-7h
q)type enlist 37       / +ve type value
7h
```

Fill (^)

```
q)/fill - used with nulls. There are three functions for processing null
values.
The dyadic function named fill replaces null values in the right
argument with
the atomic left argument.
q)100 ^ 3 4 0N 0N -5
3 4 100 100 -5
q)`Hello^``jack`herry``john`
`jack`herry`Hello`john`Hello
```

Fills

```
q)/fills - fills in nulls with the previous not null value.
q)fills 1 0N 2 0N 0N 2 3 0N -5 0N
1 1 2 2 2 2 3 3 -5 -5
```

First

```
q)/first - returns the first atom of a list
q)first 1 3 34  5 3
1
```

Flip

```
q)/flip - Monadic primitive that applies to lists and associations. It
interchan
ge the top two levels of its argument.
q)trade
time                    sym   price    size
-------------------------------------------
2009.06.18T06:04:42.919 apple 72.05742 36
2009.11.14T12:42:34.653 ibm   16.11385 12
2009.12.27T17:02:11.518 apple 68.15909 97
q)flip trade
time | 2009.06.18T06:04:42.919 2009.11.14T12:42:34.653
2009.12.27T17:02:11.518
sym  | apple                   ibm                     apple
price| 72.05742                16.11385                68.15909
size | 36                      12                      97
```

iasc

```
q)/iasc - Index ascending, return the indices of the ascended sorted
list relati
ve to the input list.
q)iasc 5 4 0 3 4 9
2 3 1 4 0 5
```

Idesc

```
q)/idesc - Index desceding, return the descended sorted list relative to
the inp
ut list
q)idesc 0 1 3 4
3 2 1 0
```

in

```
q)/in - In a list, dyadic function used to query list (on the right-hand
side) about their contents.

q)(2 4) in  1 2 3

10b
```

insert

```
q)/insert - Insert statement, upload new data into a table.

q)insert[`trade;((.z.Z);`samsung;48.35;99)]

,3

q)trade

time                    sym     price    size

---------------------------------------------

2009.06.18T06:04:42.919 apple   72.05742 36

2009.11.14T12:42:34.653 ibm     16.11385 12

2009.12.27T17:02:11.518 apple   68.15909 97

2015.04.06T10:03:36.738 samsung 48.35    99
```

key

```
q)/key - three different functions i.e. generate +ve integer number,
gives conte

nt of a directory or key of a table/dictionary.

q)key 9

0 1 2 3 4 5 6 7 8

q)key `:c:

`$RECYCLE.BIN`Config.Msi`Documents and
Settings`Drivers`Geojit`hiberfil.sys`I..
```

lower

```
q)/lower - Convert to lower case and floor

q)lower ("JoHn";`HERRY`SYM)

"john"

`herry`sym
```

Max and Min (i.e. | and &)

```
q)/Max and Min  / a|b  and a&b

q)9|7

9

q)9&5

5
```

null

```
q)/null - return 1b if the atom is a null else 0b from the argument list

q)null 1 3 3 0N

0001b
```

Peach

```
q)/peach  -  Parallel each, allows process across slaves

q)foo peach list1   / function foo applied across the slaves named in
list1

'list1

q)foo:{x+27}

q)list1:(0 1 2 3 4)

q)foo peach list1   / function foo applied across the slaves named in
list1

27 28 29 30 31
```

Prev

```
q)/prev - returns the previous element i.e. pushes list forwards

q)prev 0 1 3 4 5 7

0N 0 1 3 4 5
```

Random(?)

```
q)/random - syntax - n?list, gives random sequences of ints and floats

q)9?5

0 0 4 0 3 2 2 0 1

q)3?9.9

0.2426823 1.674133 3.901671
```

Raze

```
q)/raze - Flattn a list of lists, removes a layer of indexing from a
list of lists. for instance:
q)raze (( 12 3 4; 30 0);("hello";7 8); 1 3 4)
12 3 4
30 0
"hello"
7 8
1
3
4
```

read0

```
q)/read0        - Read in a text file
q)read0 `:c:/q/README.txt          / gives the contents of *.txt file
```

read1

```
q)/read1        - Read in a q data file
q)read1 `:c:/q/t1
0xff016200630b000500000073796d0074696d6500707269636…
```

reverse

```
q)/reverse - Reverse a list
q)reverse 2 30 29 1 3 4
4 3 1 29 30 2
q)reverse "HelloWorld"
"dlroWolleH"
```

set

```
q)/set  -  set value of a variable
q)`x set 9
`x
q)x
9
q)`:c:/q/test12 set trade
`:c:/q/test12
q)get `:c:/q/test12
time                    sym     price    size
---------------------------------------------
2009.06.18T06:04:42.919 apple   72.05742 36
2009.11.14T12:42:34.653 ibm     16.11385 12
2009.12.27T17:02:11.518 apple   68.15909 97
2015.04.06T10:03:36.738 samsung 48.35    99
2015.04.06T10:03:47.540 samsung 48.35    99
2015.04.06T10:04:44.844 samsung 48.35    99
```

ssr

```
q)/ssr - String search and replace, syntax - ssr["string";search-
string;replaced
-with]
q)ssr["HelloWorld";"o";"O"]
"HellOWOrld"
```

string

```
q)/string - converts to string, converts all types to a string format.
q)string (1 2 3; `abc;"XYZ";0b)
(,"1";,"2";,"3")
"abc"
(,"X";,"Y";,"Z")
,"0"
```

Sv

```
q)/sv - Scalar from vector, performs different tasks dependent on its
arguments.

It evaluates the base representation of numbers, which allows us to
calculate the number of seconds in a month or convert a length from feet
and inches to centimeters

q)24 60 60 sv 11 30 49

41449      / number of seconds elapsed in a day at 11:30:49
```

system

```
q)/system - allows a system command to be sent,

q)system "dir *.py"

" Volume in drive C is New Volume"

" Volume Serial Number is 8CD2-05B2"

""

" Directory of C:\\Users\\myaccount-raj"

""

"09/14/2014  06:32 PM                22 hello1.py"

"                1 File(s)            22 bytes"
```

tables

```
q)/tables - list all tables

q)tables `

`s#`tab1`tab2`trade
```

Til

```
q)/til - Enumerate

q)til 5

0 1 2 3 4
```

trim

```
q)/trim - Eliminate string spaces

q)trim "   John       "

"John"
```

vs

```
q)/vs - Vector from scaler , produces a vector quantity from a scaler
quantity

q)"|" vs "20150204|msft|20.45"

"20150204"

"msft"

"20.45"
```

xasc

```
q)/xasc  - Order table ascending, allows a table (right-hand argument)
to be sor

ted such that (left-hand argument) is in ascending order

q)`price xasc trade

time                    sym     price    size

---------------------------------------------

2009.11.14T12:42:34.653 ibm     16.11385 12

2015.04.06T10:03:36.738 samsung 48.35    99

2015.04.06T10:03:47.540 samsung 48.35    99

2015.04.06T10:04:44.844 samsung 48.35    99

2009.12.27T17:02:11.518 apple   68.15909 97

2009.06.18T06:04:42.919 apple   72.05742 36
```

xcol

```
q)/xcol -  Renames columns of a table

q)`timeNew`symNew xcol trade

timeNew                 symNew  price    size

---------------------------------------------

2009.06.18T06:04:42.919 apple   72.05742 36

2009.11.14T12:42:34.653 ibm     16.11385 12

2009.12.27T17:02:11.518 apple   68.15909 97

2015.04.06T10:03:36.738 samsung 48.35    99

2015.04.06T10:03:47.540 samsung 48.35    99

2015.04.06T10:04:44.844 samsung 48.35    99
```

xcols

```
q)/xcols  - Reorders the columns of a table,
q)`size`price xcols trade
size price    time                    sym
---------------------------------------------
36   72.05742 2009.06.18T06:04:42.919 apple
12   16.11385 2009.11.14T12:42:34.653 ibm
97   68.15909 2009.12.27T17:02:11.518 apple
99   48.35    2015.04.06T10:03:36.738 samsung
99   48.35    2015.04.06T10:03:47.540 samsung
99   48.35    2015.04.06T10:04:44.844 samsung
```

xdesc

```
q)/xdesc  - Order table descending, allows tables to be sorted such that
the left-hand argument is in descending order.
q)`price xdesc trade
time                    sym     price    size
---------------------------------------------
2009.06.18T06:04:42.919 apple   72.05742 36
2009.12.27T17:02:11.518 apple   68.15909 97
2015.04.06T10:03:36.738 samsung 48.35    99
2015.04.06T10:03:47.540 samsung 48.35    99
2015.04.06T10:04:44.844 samsung 48.35    99
2009.11.14T12:42:34.653 ibm     16.11385 12
```

xgroup

```
q)/xgroup -  Creates nested table
q)`x xgroup ([]x:9 18 9 18 27 9 9;y:10 20 10 20 30 40)
'length
q)`x xgroup ([]x:9 18 9 18 27 9 9;y:10 20 10 20 30 40 10)
x | y
--| -----------
9 | 10 10 40 10
18| 20 20
27| ,30
```

xkey

```
q)/xkey  -  Set key on table
q)`sym xkey trade
sym    | time                    price    size
-------| ------------------------------------
apple  | 2009.06.18T06:04:42.919 72.05742 36
ibm    | 2009.11.14T12:42:34.653 16.11385 12
apple  | 2009.12.27T17:02:11.518 68.15909 97
samsung| 2015.04.06T10:03:36.738 48.35    99
samsung| 2015.04.06T10:03:47.540 48.35    99
samsung| 2015.04.06T10:04:44.844 48.35    99
```

System Commands

System commands control the **q** environment. They are of the following form:

```
\cmd [p]                     where p may be optional
```

Some of the popular system commands have been discussed below:

\a [namespace] – List tables in the given namespace

```
q)/Tables in default namespace
q)\a
,`trade
q)\a .o          / table in .o namespace.
,`TI
```

\b – View dependencies

```
q)/ views/dependencies
q)a:: x+y       / global assingment
q)b:: x+1
q)\b
`s#`a`b
```

\B – Pending views / dependencies

```
q)/ Pending views/dependencies
q)a::x+1        / a depends on x
q)\B            / the dependency is pending
' / the dependency is pending
q)\B
`s#`a`b
q)\b
`s#`a`b
q)b
29
q)a
29
q)\B
`symbol$()
```

\cd – Change directory

```
q)/change directory, \cd [name]
q)\cd
"C:\\Users\\myaccount-raj"
q)\cd ../new-account
q)\cd
"C:\\Users\\new-account"
```

\d – sets current namespace

```
q)/ sets current namespace \d [namespace]
q)\d            /default namespace
'
q)\d .o         /change to .o
q.o)\d
`.o
q.o)\d .        / return to default
q)key `         /lists namespaces other than .z
`q`Q`h`j`o
q)\d .john      /change to non-existent namespace
```

```
q.john)\d
`.john
q.john)\d .
q)\d
`.
```

\l – load file or directory from db

```
q)/ Load file or directory, \l
q)\l test2.q          / loading test2.q which is stored in current
path.
ric     | date       ex     openP    closeP   MCap
--------| -----------------------------------------
JPMORGAN| 2008.05.23 SENSEX 18.30185 17.16319 17876
HSBC    | 2002.05.21 NIFTY  2.696749 16.58846 26559
JPMORGAN| 2006.09.07 NIFTY  14.15219 20.05624 14557
HSBC    | 2010.10.11 SENSEX 7.394497 25.45859 29366
JPMORGAN| 2007.10.02 SENSEX 1.558085 25.61478 20390
ric     | date       ex      openP    closeP   MCap
--------| ------------------------------------------
INFOSYS | 2003.10.30 DOW     21.2342  7.565652 2375
RELIANCE| 2004.08.12 DOW     12.34132 17.68381 4201
SBIN    | 2008.02.14 DOW     1.830857 9.006485 15465
INFOSYS | 2009.06.11 HENSENG 19.47664 12.05208 11143
SBIN    | 2010.07.05 DOW     18.55637 10.54082 15873
```

\p – port number

```
q)/ assign port number, \p
q)\p
5001i
q)\p 8888
q)\p
8888i
```

\\ - Exit from q console

```
\\ - exit

Exit form q.
```

13. BUILT-IN FUNCTIONS

The **q** programming language has a set of rich and powerful built-in functions. A built-in function can be of the following types:

- **String function** – Takes a string as input and returns a string.
- **Aggregate function** – Takes a list as input and returns an atom.
- **Uniform function** – Takes a list and returns a list of the same count.
- **Mathematical function** – Takes numeric argument and returns a numeric argument.
- **Miscellaneous function** – All functions other than above mentioned.

String Functions

Like – pattern matching

```
q)/like is a dyadic, performs pattern matching, return 1b on success
else 0b

q)"John" like "J??n"

1b

q)"John My Name" like "J*"

1b
```

ltrim – removes leading blanks

```
q)/ ltrim - monadic ltrim takes string argument, removes leading blanks

q)ltrim "   Rick "

"Rick "
```

rtrim – removes trailing blanks

```
q)/rtrim - takes string argument, returns the result of removing
trailing blanks

q)rtrim "   Rick   "

"   Rick"
```

ss – string search

```
q)/ss - string search, perform pattern matching, same as "like" but
return the indices of the matches of the pattern in source.

q)"Life is beautiful" ss "i"

1 5 13
```

trim – removes leading and trailing blanks

```
q)/trim - takes string argument, returns the result of removing leading
& traili

ng blanks

q)trim " John       "

"John"
```

Mathematical Functions

acos – inverse of cos

```
q)/acos - inverse of cos, for input between -1 and 1, return float
between 0 and pi

q)acos 1

0f

q)acos -1

3.141593

q)acos 0

1.570796
```

cor – gives correlation

```
q)/cor - the dyadic takes two numeric lists of same count, returns a
correlation between the items of the two arguments

q)27 18 18 9 0 cor 27 36 45 54 63

-0.9707253
```

cross – Cartesian product

```
q)/cross - takes atoms or lists as arguments and returns their Cartesian
product
```

```
q)9 18 cross `x`y`z
9  `x
9  `y
9  `z
18 `x
18 `y
18 `z
```

var - variance

```
q)/var - monadic, takes a scaler or numeric list and returns a float
equal to the mathematical variance of the items
q)var 45
0f
q)var 9 18 27 36
101.25
```

wavg

```
q)/wavg - dyadic, takes two numeric lists of the same count and returns
the aver
age of the second argument weighted by the first argument.
q)1 2 3 4 wavg 200 300 400 500
400f
```

Aggregate Functions

all – & operation

```
q)/all - monadic, takes a scaler or list of numeric type and returns the
result
of & applied across the items.
q)all 0b
0b
q)all 9 18 27 36
1b
q)all 10 20 30
```

```
1b
```

Any - | operation

```
q)/any - monadic, takes scaler or list of numeric type and the return
the result of | applied across the items

q)any 20 30 40 50

1b

q)any 20012.02.12 2013.03.11

'20012.02.12
```

prd – arithmetic product

```
q)/prd - monadic, takes scaler, list, dictionary or table of numeric
type and returns the arithmetic product.

q)prd `x`y`z! 10 20 30

6000

q)prd ((1 2; 3 4);(10 20; 30 40))

10 40

90 160
```

Sum – arithmetic sum

```
q)/sum - monadic, takes a scaler, list,dictionary or table of numeric
type and returns the arithmetic sum.

q)sum 2 3 4 5 6

20

q)sum (1 2; 4 5)

5 7
```

Uniform Functions

Deltas – difference from its previous item.

```
q)/deltas -takes a scalar, list, dictionary or table and returns the
difference of

 each item from its predecessor.

q)deltas 2 3 5 7 9

2 1 2 2 2

q)deltas `x`y`z!9 18 27

x| 9

y| 9

z| 9
```

fills – fills nulls value

```
q)/fills - takes scalar, list, dictionary or table of numeric type and
returns a c

copy of the source in which non-null items are propagated forward to
fill nulls

q)fills 1 0N 2 0N 4

1 1 2 2 4

q)fills `a`b`c`d! 10 0N 30 0N

a| 10

b| 10

c| 30

d| 30
```

maxs – cumulative maximum

```
q)/maxs - takes scalar, list, dictionary or table and returns the
cumulative maximum of the source items.

q)maxs 1 2 4 3 9 13 2

1 2 4 4 9 13 13

q)maxs `a`b`c`d!9 18 0 36

a| 9

b| 18

c| 18

d| 36
```

Miscellaneous Functions

Count – return number of element

```
q)/count - returns the number of entities in its argument.

q)count 10 30 30

3

q)count (til 9)

9

q)count ([]a:9 18 27;b:1.1 2.2 3.3)

3
```

Distinct – return distinct entities

```
q)/distinct - monadic, returns the distinct entities in its argument

q)distinct 1 2 3 4 2 3 4 5 6 9

1 2 3 4 5 6 9
```

Except – element not present in second arg.

```
q)/except - takes a simple list (target) as its first argument and
returns a list containing the items of target that are not in its second
argument

q)1 2 3 4 3 1 except 1

2 3 4 3
```

fill – fill null with first argument

```
q)/fill (^) - takes an atom as its first argument and a list(target) as
its second argument and return a list obtained by substituting the first
argument for every occurrence of null in target

q)42^ 9 18 0N 27 0N 36

9 18 42 27 42 36

q)";"^"Life is Beautiful"

"Life;is;Beautiful"
```

14. QUERIES

Queries in **q** are shorter and simpler and extend the capabilities of sql. The main query expression is the 'select expression', which in its simplest form extracts sub-tables but it can also create new columns.

The general form of a **Select expression** is as follows:

```
Select columns by columns from table where conditions
```

****Note**: **by** & **where** phrases are optional, only the 'from expression' is mandatory.

In general, the syntax will be:

```
select [a] [by b] from t [where c]

update [a] [by b] from t [where c]
```

The syntax of **q** expressions look quite similar to SQL, but **q** expressions are simple and powerful. An equivalent sql expression for the above **q** expression would be as follows:

```
select [b] [a] from t [where c] [group by b order by b]

update t set [a] [where c]
```

All the clauses execute on the columns and therefore **q** can take advantage of order. As Sql queries are not based on order, they cannot take that advantage.

q relational queries are generally much smaller in size as compared to their corresponding sql. Ordered and functional queries do things that are difficult in sql.

In a historical database, the ordering of the **where** clause is very important because it affects the performance of the query. The **partition** variable (date/month/day) always comes first followed by the sorted and indexed column (generally the sym column).

For example,

```
select from table where date in d, sym in s
```

is much faster than,

```
select from table where sym in s, date in d
```

Basics Queries

Let’s write a query script in notepad (as below), save (as *.q), and then load it.

```
sym:asc`AIG`CITI`CSCO`IBM`MSFT;

ex:"NASDAQ"

dst:`$":c:/q/test/data/";          /database destination

@[dst;`sym;:;sym];

n:1000000;

trade:([]sym:n?`sym;time:10:30:00.0+til
n;price:n?3.3e;size:n?9;ex:n?ex);

quote:([]sym:n?`sym;time:10:30:00.0+til
n;bid:n?3.3e;ask:n?3.3e;bsize:n?9;asize:n?9;ex:n?ex);

{@[;`sym;`p#]`sym xasc x}each`trade`quote;

d:2014.08.07 2014.08.08 2014.08.09 2014.08.10 2014.08.11; /Date vector
can also be changed by the user

dt:{[d;t].[dst;(`$string d;t;`);:;value t]};

d dt/:\:`trade`quote;

Note: Once you run this query, two folders .i.e. "test" and "data" will
be created under "c:/q/", and date partition data can be seen inside
data folder.
```

Queries with Constraints

***Denotes HDB query**

Select all IBM trades

```
select from trade where sym in `IBM
```

***Select all IBM trades on a certain day**

```
thisday: 2014.08.11

select from trade where date=thisday,sym=`IBM
```

Select all IBM trades with a price >100

```
select from trade where sym=`IBM, price>100.0
```

Select all IBM trades with a price less than or equal to 100

```
select from trade where sym=`IBM,not price>100.0
```

*Select all IBM trades between 10.30 and 10.40, in the morning, on a certain date

```
thisday: 2014.08.11

select from trade where
date=thisday,sym=`IBM,time>10:30:00.000,time<10:40:00.000
```

Select all IBM trades in ascending order of price

```
`price xasc select from trade where sym=`IBM
```

*Select all IBM trades in descending order of price in a certain time frame

```
`price xdesc select from trade where date within 2014.08.07 2014.08.11,
sym=`IBM
```

Composite sort – sort ascending order by sym and then sort the result in descending order of price

```
`sym xasc `price xdesc select from trade where date=2014.08.07,size=5
```

Select all IBM or MSFT trades

```
select from trade where sym in `IBM`MSFT
```

*Calculate count of all symbols in ascending order within a certain time frame

```
`numsym xasc select numsym: count i by sym from trade where date within
2014.08.07 2014.08.11
```

*Calculate count of all symbols in descending order within a certain time frame

```
`numsym xdesc select numsym: count i by sym from trade where date within
2014.08.07 2014.08.11
```

*** What is the maximum price of IBM stock within a certain time frame, and when does this first happen?**

```
select time,ask from quote where date within 2014.08.07 2014.08.11,
sym=`IBM, ask=exec first ask from select max ask from quote where
sym=`IBM
```

Select the last price for each sym in hourly buckets

```
select last price by hour:time.hh, sym from trade
```

Queries with Aggregations

*** Calculate vwap (Volume Weighted Average Price) of all symbols**

```
select vwap:size wavg price by sym from trade
```

*** Count the number of records (in millions) for a certain month**

```
(select trade:1e-6*count i by date.dd from trade where
date.month=2014.08m) +select quote:1e-6*count i by date.dd from quote
where date.month=2014.08m
```

*** HLOC – Daily High, Low, Open and Close for CSCO in a certain month**

```
select high:max price,low:min price,open:first price,close:last price by
date.dd from trade where date.month=2014.08m,sym=`CSCO
```

*** Daily Vwap for CSCO in a certain month**

```
select vwap:size wavg price by date.dd from trade where
date.month=2014.08m ,sym=`CSCO
```

*** Calculate the hourly mean, variance and standard deviation of the price for AIG**

```
select mean:avg price, variance:var price, stdDev:dev price by date,
hour:time.hh from trade where sym=`AIG
```

Select the price range in hourly buckets

```
select range:max[price] – min price by date,sym,hour:time.hh from trade
```

*** Daily Spread (average bid-ask) for CSCO in a certain month**

```
select spread:avg bid-ask by date.dd from quote where
date.month=2014.08m, sym=`CSCO
```

*** Daily Traded Values for all syms in a certain month**

```
select dtv:sum size by date,sym from trade where date.month=2014.08m
```

Extract a 5 minute vwap for CSCO

```
select size wavg price by 5 xbar time.minute from trade where sym=`CSCO
```

*** Extract 10 minute bars for CSCO**

```
select high:max price,low:min price,close:last price by date,10 xbar
time.minute from trade where sym=`CSCO
```

*** Find the times when the price exceeds 100 basis points (100e-4) over the last price for CSCO for a certain day**

```
select time from trade where date=2014.08.11,sym=`CSCO,price>1.01*last
price
```

*** Full Day Price and Volume for MSFT in 1 Minute Intervals for the last date in the database**

```
select last price,last size by time.minute from trade where date=last
date, sym=`MSFT
```

15. INTER-PROCESS COMMUNICATION

KDB+ allows one process to communicate with another process through inter-process communication. Kdb+ processes can connect to any other kdb+ on the same computer, the same network, or even remotely. We just need to specify the port and then the clients can talk to that port. Any **q** process can communicate with any other **q** process as long as it is accessible on the network and is listening for connections.

- a server process listens for connections and processes any requests

- a client process initiates the connection and sends commands to be executed

Client and server can be on the same machine or on different machines. A process can be both a client and a server.

A communication can be,

- **Synchronous** (wait for a result to be returned)
- **Asynchronous** (no wait and no result returned)

Initialize Server

A **q** server is initialized by specifying the port to listen on,

```
q -p 5001         / command line
\p 5001           / session command
```

Communication Handle

A *communication handle* is a symbol that starts with "**:**" and has the form:

```
`:[server]:port-number
```

Example

```
`::5001               / server and client on same machine
`:jack:5001           / server on machine jack
`:192.168.0.156       / server on specific IP address
`:www.myfx.com:5001   / server at www.myfx.com
```

To start the connection, we use the function "hopen" which returns an integer connection handle. This handle is used for all subsequent client requests. For example:

```
q)h:hopen `::5001

q)h"til 5"

0 1 2 3 4

q)hclose h
```

Synchronous and Asynchronous Messages

Once we have a handle, we can send a message either synchronously or asynchronously.

Synchronous Message: Once a message is sent, it waits on and returns the result. Its format is as follows:

```
     handle "message"
```

Asynchronous Message: After sending a message, start processing the next statement immediately without having to wait and return a result. Its format is as follows:

```
     neg[handle] "message"
```

Messages that require a response, for example function calls or select statements, will normally use the synchronous form; while messages that need not return an output, for example inserting updates to a table, will be asynchronous.

16. MESSAGE HANDLER (.Z LIBRARY)

When a **q** process connects to another **q** process via inter-process communication, it is processed by message handlers. These message handlers have a default behavior. For example, in case of synchronous message handling, the handler returns the value of the query. The synchronous handler in this case is **.z.pg**, which we could override as per requirement.

Kdb+ processes have several pre-defined message handlers. Message handlers are important for configuring the database. Some of the usages include:

- **Logging** – Log incoming messages (helpful in case of any fatal error),
- **Security** – Allow/disallow access to the database, certain function calls, etc., based on username / ip address. It helps in providing access to authorized subscribers only.
- **Handle connections/disconnections** from other processes.

Predefined Message Handlers

Some of the predefined message handlers are discussed below.

.z.pg

It is a synchronous message handler (process get). This function gets called automatically whenever a sync message is received on a kdb+ instance.

Parameter is the string/function call to be executed, i.e., the message passed. By default, it is defined as follows:

```
.z.pg: {value x}                    / simply execute the message
                                    received but we can overwrite it to
                                    give any customized result.

.z.pg : {handle::.z.w;value x}     / this will store the remote handle

.z.pg : {show .z.w;value x}        / this will show the remote handle
```

.z.ps

It is an asynchronous message handler (process set). It is the equivalent handler for asynchronous messages. Parameter is the string/function call to be executed. By default, it is defined as,

```
.z.pg : {value x}           / Can be overriden for a customized action.
```

Following is the customized message handler for asynchronous messages, where we have used the protected execution,

```
.z.pg: {@[value; x; errhandler x]}
```

Here **errhandler** is a function used in case of any unexpected error.

.z.po[]

It is a connection open handler (process-open). It is executed when a remote process opens a connection. To see the handle when a connection to a process is opened, we can define the .z.po as,

```
.z.po : {Show “Connection opened by” , string h: .z.h}
```

.z.pc[]

It is a close connection handler (process-close). It is called when a connection is closed. We can create our own close handler which can reset the global connection handle to 0 and issue a command to set the timer to fire (execute) every 3 seconds (3000 milliseconds).

```
.z.pc : { h::0; value “\\t 3000”}
```

The timer handler (.z.ts) attempts to re-open the connection. On success, it turns the timer off.

```
.z.ts : { h:: hopen `::5001; if [h>0; value “\\t 0”] }
```

.z.pi[]

PI stands for process input. It is called for any sort of input. It can be used to handle console input or remote client input. Using .z.pi[], one can validate the console input or replace the default display. In addition, it can be used for any sort of logging operations.

```
q).z.pi
'.z.pi
q).z.pi:{">", .Q.s value x}
q)5+4
>9
q)30+42
>72
q)30*2
>60
```

```
q)\x .z.pi
>q)
q)5+4
9
```

.z.pw

It is a validation connection handler (user authentication). It adds an extra callback when a connection is being opened to a kdb+ session. It is called after the –u/-U checks and before the .z.po (port open).

```
.z.pw : {[user_id;passwd] 1b}
```

Inputs are **userid** (symbol) and **password** (text).

PART 3: ADVANCED TOPICS

17. ATTRIBUTES

Lists, dictionaries, or columns of a table can have attributes applied to them. Attributes impose certain properties on the list. Some attributes might disappear on modification.

Types of Attributes

Sorted (`s#)

`s# means the list is sorted in an ascending order. If a list is explicitly sorted by asc (or xasc), the list will automatically have the sorted attribute set.

```
q)L1: asc 40 30 20 50 9 4

q)L1

`s#4 9 20 30 40 50
```

A list which is known to be sorted can also have the attribute explicitly set. **Q** will check if the list is sorted, and if is not, an **s-fail** error will be thrown.

```
q)L2:30 40 24 30 2

q)`s#L2

's-fail
```

The sorted attribute will be lost upon an unsorted append.

Parted (`p#)

`p# means the list is parted and identical items are stored contiguously.

The range is an **int** or **temporal type** having an underlying int value, such as years, months, days, etc. You can also partition over a symbol provided it is enumerated.

Applying the parted attribute creates an index dictionary that maps each unique output value to the position of its first occurrence. When a list is parted, lookup is much faster, since linear search is replaced by hashtable lookup.

```
q)L:`p# 99 88 77 1 2 3

q)L

`p#99 88 77 1 2 3

q)L,:3

q)L
```

```
99 88 77 1 2 3 3
```

Note:

- The parted attribute is not preserved under an operation on the list, even if the operation preserves the partitioning.

- The parted attribute should be considered when the number of entities reaches a billion and most of the partitions are of substantial size, i.e., there is significant repetition.

Grouped (`g#)

`g# means the list is grouped. An internal dictionary is built and maintained which maps each unique item to each of its indices, requiring considerable storage space. For a list of length **L** containing **u** unique items of size **s**, this will be **(L × 4) + (u × s)** bytes.

Grouping can be applied to a list when no other assumptions about its structure can be made.

The attribute can be applied to any typed lists. It is maintained on appends, but lost on deletes.

```
q)L: `g# 1 2 3 4 5 4 2 3 1 4 5 6
q)L
`g#1 2 3 4 5 4 2 3 1 4 5 6
q)L,:9
q)L
`g#1 2 3 4 5 4 2 3 1 4 5 6 9
q)L _:2
q)L
1 2 4 5 4 2 3 1 4 5 6 9
```

Unique (`#u)

Applying the unique attribute (`u#) to a list indicates that the items of the list are distinct. Knowing that the elements of a list are unique dramatically speeds up **distinct** and allows **q** to execute some comparisons early.

When a list is flagged as unique, an internal hash map is created to each item in the list. Operations on the list must preserve uniqueness or the attribute is lost.

```
q)LU:`u#`MSFT`SAMSUNG`APPLE
q)LU
`u#`MSFT`SAMSUNG`APPLE
q)LU,:`IBM                        /Uniqueness preserved
q)LU
`u#`MSFT`SAMSUNG`APPLE`IBM
q)LU,:`SAMSUNG                    / Attribute lost
q)LU
`MSFT`SAMSUNG`APPLE`IBM`SAMSUNG
```

Note:

- `u# is preserved on concatenations which preserve the uniqueness. It is lost on deletions and non-unique concatenations.

- Searches on `u# lists are done via a hash function.

Removing Attributes

Attributes can be removed by applying **`#**.

Applying Attributes

Three formats for applying attributes are:

- **L: `s# 14 2 3 3 9** / Specify during list creation

- **@[`.; `L ; `s#]** / Functional apply, i.e. to the variable list L
/ in the default namespace (i.e. `.) apply
/ the sorted `s# attribute

- **Update `s#time from `tab**
/ Update the table (tab) to apply the
/ attribute.

Let's apply the above three different formats with examples.

```
q)/ set the attribute during creation
q)L:`s# 3 4 9 10 23 84 90
q)/apply the attribute to existing list data
q)L1: 9 18 27 36 42 54
q)@[`.;`L1;`s#]
`.
```

```
q)L1                   / check
`s#9 18 27 36 42 54
q)@[`.;`L1;`#]         / clear attribute
`.
q)L1
9 18 27 36 42 54
q)/update a table to apply the attribute
q)t: ([] sym:`ibm`msft`samsung; mcap:9000 18000 27000)
q)t:([]time:09:00 09:30 10:00t;sym:`ibm`msft`samsung; mcap:9000 18000
27000)
q)t
time         sym     mcap
--------------------------
09:00:00.000 ibm     9000
09:30:00.000 msft    18000
10:00:00.000 samsung 27000
q)update `s#time from `t
`t
q)meta t           / check it was applied
c   | t f a
----| -----
time| t   s
sym | s
mcap| j
Above we can see that the attribute column in meta table results shows
the time column is sorted (`s#).
```

18. FUNCTIONAL QUERIES

Functional (Dynamic) queries allow specifying column names as symbols to typical q-sql select/exec/delete columns. It comes very handy when we want to specify column names dynamically.

The functional forms are:

```
?[t;c;b;a]       / for select
![t;c;b;a]       / for update
```

where

- **t** is a table;
- **a** is a dictionary of aggregates;
- **b** the by-phrase; and
- **c** is a list of constraints.

Note:

- All **q** entities in **a**, **b**, and **c** must be referenced by name, meaning as symbols containing the entity names.

- The syntactic forms of select and update are parsed into their equivalent functional forms by the **q** interpreter, so there is no performance difference between the two forms.

Functional select

The following code block shows how to use **functional select**:

```
q)t:([]n:`ibm`msft`samsung`apple;p:40 38 45 54)
q)t
n       p
----------
ibm     40
msft    38
samsung 45
apple   54
q)select m:max p,s:sum p by name:n from t where p>36, n in
`ibm`msft`apple
```

```
name | m  s
-----| -----
apple| 54 54
ibm  | 40 40
msft | 38 38
```

Example 1

Let's start with the easiest case, the functional version of "**select from t**" will look like:

```
q)?[t;();0b;()]  / select from t
n       p
----------
ibm     40
msft    38
samsung 45
apple   54
```

Example 2

In the following example, we use the enlist function to create singletons to ensure that appropriate entities are lists.

```
q)wherecon: enlist (>;`p;40)
q)?[`t;wherecon;0b;()]       / select from t where p>40
n       p
----------
samsung 45
apple   54
```

Example 3

```
q)groupby: enlist[`p] ! enlist `p
q)selcols: enlist [`n]!enlist `n
q)?[ `t;(); groupby;selcols]            / select n by p from t
p | n
--| -------
38| msft
```

```
40| ibm
45| samsung
54| apple
```

Functional Exec

The functional form of exec is a simplified form of **select**.

```
q)?[t;();();`n]               / exec n from t (functional form of exec)
`ibm`msft`samsung`apple

q)?[t;();`n;`p]              / exec p by n from t (functional exec)
apple  | 54
ibm    | 40
msft   | 38
samsung| 45
```

Functional Update

The functional form of update is completely analogous to that of **select**. In the following example, the use of enlist is to create singletons, to ensure that input entities are lists.

```
q)c:enlist (>;`p;0)
q)b: (enlist `n)!enlist `n
q)a: (enlist `p) ! enlist (max;`p)
q)![t;c;b;a]
n       p
----------
ibm     40
msft    38
samsung 45
apple   54
```

Functional delete

Functional delete is a simplified form of functional update. Its syntax is as follows:

```
![t;c;0b;a]     / t is a table, c is a list of where constraints, a is a
                / list of column names
```

Let us now take an example to show how functional delete work:

```
q)![t; enlist (=;`p; 40); 0b;`symbol$()]

                                         / delete from t where p = 40

n       p

----------

msft    38

samsung 45

apple   54
```

19. TABLE ARITHMETIC

In this chapter, we will learn how to operate on dictionaries and then tables. Let's start with dictionaries:

```
q)d:`u`v`x`y`z! 9 18 27 36 45            / Creating a dictionary d
q)/ key of this dictionary (d) is given by
q)key d
`u`v`x`y`z
q)/and the value by
q)value d
9 18 27 36 45
q)/a specific value
q)d`x
27
q)d[`x]
27
q)/values can be manipulated by using the arithmetic operator +-*% as,
q)45 + d[`x`y]
72 81
```

If one needs to amend the dictionary values, then the amend formulation can be:

```
q)@[`d;`z;*;9]
`d
q)d
u| 9
v| 18
x| 27
y| 36
q)/Example, table tab
q)tab:([]sym:`;time:0#0nt;price:0n;size:0N)
q)n:10;sym:`IBM`SAMSUNG`APPLE`MSFT
q)insert[`tab;(n?sym;("t"$.z.Z);n?100.0;n?100)]
```

```
0 1 2 3 4 5 6 7 8 9
q)`time xasc `tab
`tab
q)/ to get particular column from table tab
q)tab[`size]
12 10 1 90 73 90 43 90 84 63
q)tab[`size]+9
21 19 10 99 82 99 52 99 93 72
z| 405



q)/Example table tab
q)tab:([]sym:`;time:0#0nt;price:0n;size:0N)
q)n:10;sym:`IBM`SAMSUNG`APPLE`MSFT
q)insert[`tab;(n?sym;("t"$.z.Z);n?100.0;n?100)]
0 1 2 3 4 5 6 7 8 9
q)`time xasc `tab
`tab
q)/ to get particular column from table tab
q)tab[`size]
12 10 1 90 73 90 43 90 84 63
q)tab[`size]+9
21 19 10 99 82 99 52 99 93 72



q)/We can also use the @ amend too
q)@[tab;`price;-;2]
sym     time         price    size
----------------------------------
APPLE   11:16:39.779 6.388858 12
MSFT    11:16:39.779 17.59907 10
IBM     11:16:39.779 35.5638  1
SAMSUNG 11:16:39.779 59.37452 90
APPLE   11:16:39.779 50.94808 73
```

```
SAMSUNG 11:16:39.779 67.16099 90
APPLE   11:16:39.779 20.96615 43
SAMSUNG 11:16:39.779 67.19531 90
IBM     11:16:39.779 45.07883 84
IBM     11:16:39.779 61.46716 63
q)/if the table is keyed
q)tab1:`sym xkey tab[0 1 2 3 4]
q)tab1
sym    | time         price    size
-------| --------------------------
APPLE  | 11:16:39.779 8.388858 12
MSFT   | 11:16:39.779 19.59907 10
IBM    | 11:16:39.779 37.5638  1
SAMSUNG| 11:16:39.779 61.37452 90
APPLE  | 11:16:39.779 52.94808 73

q)/To work on specific column, try this
q){tab1[x]`size} each sym
1 90 12 10
q)(0!tab1)`size
12 10 1 90 73
q)/once we got unkeyed table, manipulation is easy
q)2+ (0!tab1)`size
14 12 3 92 75
```

20. TABLES ON DISK

Data on your hard disk (also called historical database) can be saved in three different formats: Flat Files, Splayed Tables, and Partitioned Tables. Here we will learn how to use these three formats to save data.

Flat file

Flat files are fully loaded into memory which is why their size (memory footprint) should be small. Tables are saved on disk entirely in one file (so size matters).

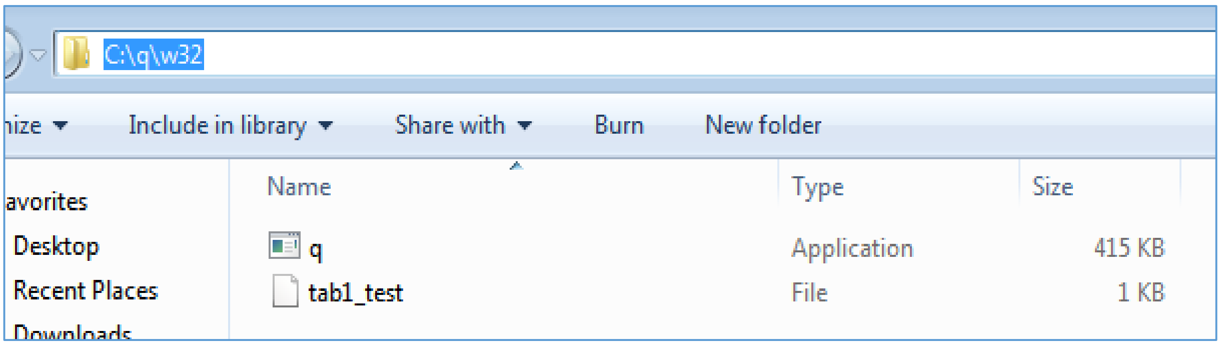
The functions used to manipulate these tables are **set/get**:

```
`:path_to_file/filename set tablename
```

Let's take an example to demonstrate how it works:

```
q)tables `.
`s#`t`tab`tab1
q)`:c:/q/w32/tab1_test set tab1
`:c:/q/w32/tab1_test
```

In Windows environment, flat files are saved at the location: **C:\q\w32**



Name	Type	Size
q	Application	415 KB
tab1_test	File	1 KB

Get the flat file from your disk (historical db) and use the **get** command as follows:

```
q)tab2: get `:c:/q/w32/tab1_test
q)tab2
sym     | time          price    size
-------| --------------------------
APPLE   | 11:16:39.779 8.388858 12
```

```
MSFT   | 11:16:39.779 19.59907 10
IBM    | 11:16:39.779 37.5638  1
SAMSUNG| 11:16:39.779 61.37452 90
APPLE  | 11:16:39.779 52.94808 73
```

A new table is created **tab2** with its contents stored in **tab1_test** file.

Splayed Tables

If there are too many columns in a table, then we store such tables in splayed format, i.e., we save them on disk in a directory. Inside the directory, each column is saved in a separate file under the same name as the column name. Each column is saved as a list of corresponding type in a kdb+ binary file.

Saving a table in splayed format is very useful when we have to access only a few columns frequently out of its many columns. A splayed table directory contains **.d** binary file which contains the order of the columns.

Much like a flat file, a table can be saved as splayed by using the **set** command. To save a table as splayed, the file path should end with a backlash:

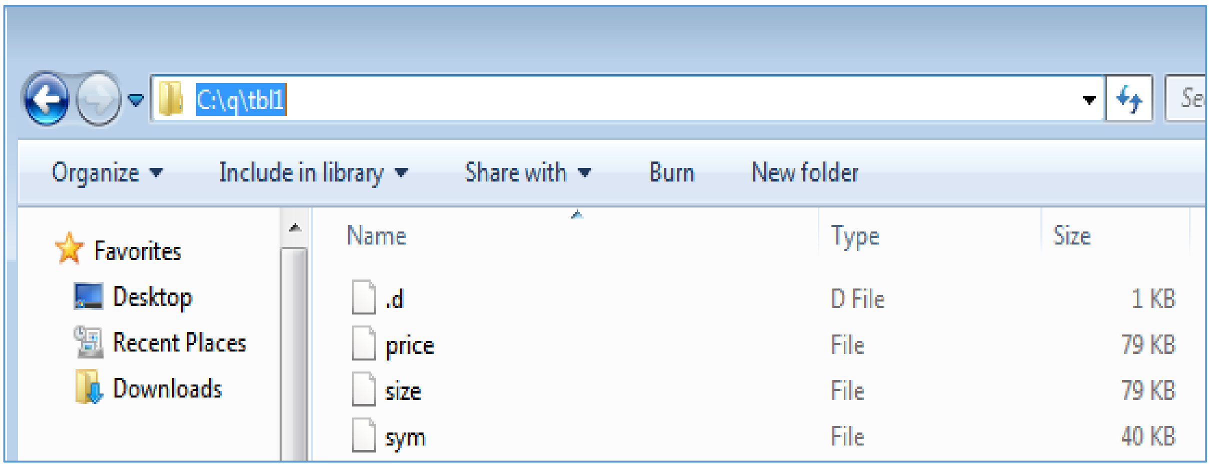
```
`:path_to_filename/filename/ set tablename
```

For reading a splayed table, we can use the **get** function:

```
tablename: get `:path_to_file/filename
```

Note: For a table to be saved as splayed, it should be un-keyed and enumerated.

In Windows environment, your file structure will appear as follows:



Name	Type	Size
.d	D File	1 KB
price	File	79 KB
size	File	79 KB
sym	File	40 KB

Partitioned Tables

Partitioned tables provide an efficient means to manage huge tables containing significant volumes of data. Partitioned tables are splayed tables spread across more partitions (directories).

Inside each partition, a table will have its own directory, with the structure of a splayed table. The tables could be split on a day/month/year basis in order to provide optimized access to its content.

To get the content of a partitioned table, use the following code block:

```
q)get `:c:/q/data/2000.01.13      // "get" command used, sample folder

quote| +`sym`time`bid`ask`bsize`asize`ex!(`p#`sym!0 0 0 0 0 0 0 0 0 0 0
0 0 0….

trade| +`sym`time`price`size`ex!(`p#`sym!0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 ….
```

Let's try to get the contents of a trade table:

```
q)get `:c:/q/data/2000.01.13/trade

sym time         price     size ex

----------------------------------

0   09:30:00.496 0.4092016 7    T

0   09:30:00.501 1.428629  4    N

0   09:30:00.707 0.5647834 6    T

0   09:30:00.781 1.590509  5    T

0   09:30:00.848 2.242627  3    A

0   09:30:00.860 2.277041  8    T

0   09:30:00.931 0.8044885 8    A

0   09:30:01.197 1.344031  2    A

0   09:30:01.337 1.875     3    A

0   09:30:01.399 2.187723  7    A
```

Note: The partitioned mode is suitable for tables with millions of records per day (i.e. time series data)

Sym file

The sym file is a kdb+ binary file containing the list of symbols from all splayed and partitioned tables. It can be read with,

```
     get `:sym
```

par.txt file (optional)

This is a configuration file, used when partitions are spread on several directories/disk drives, and contain the paths to the disk partitions.

21. MAINTENANCE FUNCTIONS

.Q.en

.Q.en is a dyadic function which help in splaying a table by enumerating a symbol column. It is especially useful when we are dealing with historical db (splayed, partition tables etc.). :

```
.Q.en[`:directory;table]
```

where **directory** is the home directory of the historical database where **sym file** is located and **table** is the table to be enumerated.

Manual enumeration of tables is not required to save them as splayed tables, as this will be done by:

```
.Q.en[`:directory_where_symbol_file_stored]table_name
```

.Q.dpft

The **.Q.dpft** function helps in creating partitioned and segmented tables. It is advanced form of **.Q.en**, as it not only splays the table but also creates a partition table.

There are four arguments used in **.Q.dpft**:

1. symbolic file handle of the database where we want to create a partition,
2. **q** data value with which we are going to partition the table,
3. name of the field with which parted (`p#) attribute is going to be applied (usually `sym), and
4. the table name.

Let’s take an example to see how it works:

```
q)tab:([]sym:5?`msft`hsbc`samsung`ibm;time:5?(09:30:30);price:5?30.25)

q).Q.dpft[`:c:/q/;2014.08.24;`sym;`tab]

`tab

q)delete tab from `

'type
```

```
q)delete tab from `/
'type
q)delete tab from .
'type
q)delete tab from `.
`.
q)tab
'tab
```

We have deleted the table **tab** from the memory. Let us now load it from the db.

```
q)\l c:/q/2014.08.24/
q)\a
,`tab
q)tab
sym     time     price
-------------------------
hsbc    07:38:13 15.64201
hsbc    07:21:05 5.387037
msft    06:16:58 11.88076
msft    08:09:26 12.30159
samsung 04:57:56 15.60838
```

.Q.chk

.Q.chk is a monadic function whose single parameter is the symbolic file handle of the root directory. It creates empty tables in a partition, wherever necessary, by examining each partition subdirectories in the root.

```
.Q.chk `:directory
```

where **directory** is the home directory of the historical database.

22. KDB+ – FAQS

The Basics

1. **What are the main components of KDB+ database?**

   Ans: The main components of KDB+ database are:

   - **Feed Handler** – It captures and processes the raw feed it gets from different sources. It parses and converts the data in a format which kdb+ can understand.

   - **The Ticker Plant** – Heart of the kdb+ database. It acts as a bridge between feeds/feed handler and the subscriber (rdb, real time tick subscribers… etc.)

   - **Real-time database** – It stores today's data. KDB+ processes, stores, and analyzes this data.

   - **Historical database** – It stores data before today. To calculate the estimates or company performance in past, we need to have the historical data.

2. **Start a new q session.**

   Ans: Start the q session by running the **q.exe** file from the location where you have copied the kdb+.

   There are three different ways to start a **q** session in Windows platform. Refer Chapter 3.

3. **Define y as x divided by 28.**

```
y : x % 28
```

4. **Write a dyadic function, fxy, which calculates the square of x divided by the square of y.**

```
fxy : (x *x ) % (y * y)
```

5. **In a script, define x as 6, y as 7, and z as 8. Then define a function, fxyz, which calculates the average of x, y, z. Load this script into q and run the command "fxyz[x;y;z]" to ensure it has been successful.**

```
x:6;y:7;z:8;


fxyz:{[x;y;z] (x+y+z)%3}
```

   /Load the above script (let suppose its name is test1.q) by " \l test1.q " and run command fxyz[x;y;z]

6. **Return a list of all functions defined in the current workspace.**

```
\f
```

7. **Return a list of all variables defined in the current workspace.**

```
\v
```

8. **Quit the q session.**

```
//
```

Data Types and Structure

1. **Compare the datatype values of 7,8f, 2 3 4f, 5 6 9 and (20f;30;40j)**

```
each (7;8f;2 3 4f;5 6 9;(20f;30;40j))
```

2. **Extract the month, week, and year from the date 20014.02.12.**

```
q)d:2014.02.12
q)d.year
2014i
q)`year$d
2014i
q)`month$d
2014.02m
q)d.month
2014.02m
```

```
q)`week$d
2014.02.10
```

3. **Cast the string "HelloWorld" to a symbol and concatenate to the end of the simple list L1:`abc`def`ghi**

```
q)`abc`def`ghi,`$("HelloWorld")
`abc`def`ghi`HelloWorld
```

4. **Make a dictionary containing the following information:**

```
`x: 9 8 7
`y: "HelloWorld"
`z: 9.87654
```

```
q)dict1:`x`y`z ! (9 8 7; "Hello World";9.87654)
q)dict1
x| 9 8 7
y| "Hello World"
z| 9.87654
q)type dict1
99h
```

List

1. **Create a list of 10 integers of type long number and store it in x.**

```
x:9 2 3 3 3 4 4 9 9 10
```

2. **Create another list of long called y and then create a list z which is x joined y.**

```
q)y: 20 30 49 30 40 30
q)z:x,y
q)z
9 2 3 3 3 4 4 9 9 10 20 30 49 30 40 30
```

3. **Calculate the number of elements in z which are greater than 4.**

```
q)z where z>4
9 9 9 10 20 30 49 30 40 30
```

4. **Calculate the sum of elements in z which are greater than 4.**

```
q)sum (z where z>4)
236
```

5. **Create two lists a and b containing 10 random integer numbers.**

```
q)a
4 2 7 8 5 6 4 1 3 3
q)b
7 8 2 1 4 2 8 0 5 8
```

6. **Calculate the union and intersection of a and b.**

```
q)a inter b
4 2 7 8 5 4 1
q)a union b
4 2 7 8 5 6 1 3 0
```

Indexing & Mixed type

1. **Create a list called x to store the string "Hello" and "World".**

```
q)x:("Hello";"World")
q)x
"Hello"
"World"
```

2. **Create a list called f containing the following elements :**
   a) The symbols `ab and `bc.
   b) The number 9
   c) The list x

```
q)f:(`ab`bc;9;x)
```

3. **Extract the symbol `bc from f.**

```
q)f[0;1]
`bc
```

4. **Extract the character string “Hello” from f.**

```
q)f[2;0]
"Hello"
```

Dictionaries

1. **Create two dictionaries,**

   d1:`x1`y1`z1!9 18 27

   and

   d2:`x11`y11`z11!5 10 15

   What are their types?

```
q)d1:`x1`y1`z1!9 18 27
q)d2:`x11`y11`z11! 5 10 27
q)d1
x1| 9
y1| 18
z1| 27
q)d2
x11| 5
y11| 10
z11| 27
q)type each (d1;d2)
99 99h
```

2. **Create a dictionary d which is a combination of d1 and d2.**

```
q)d:d1,d2
q)d
x1 | 9
y1 | 18
z1 | 27
x11| 5
y11| 10
z11| 27
```

3. **Extract the keys of dictionary d.**

```
q)key d
`x1`y1`z1`x11`y11`z11
```

4. **Use join each (,’) to concatenate d1 and d2. Observe the result.**

```
q)d1,'d2
x1 | 9
y1 | 18
z1 | 27
x11|    5
y11|    10
z11|    27
```

Functions

1. **Let x be defined as 2021 20 21 4244 3720 999 -203. Calculate the average of x.**

```
q)x:2012 20 21 4244 3720 999 -203
q)y: avg x      / In built function to calculate the avg of list of
numbers
q)y
1544.714
```

2. **Create the integer sequence 30–50, i.e., 30, 31, … 49.**

```
q)30+til 20
30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
```

3. **What is the weighted average of x if we apply the weightings 26 39 47 54 30 18 37 32?**

```
q)x
2012 20 21 4244 3720 999 -203
q)x wavg 26 47 54 30 18 37 32   / In-built function wavg to
calculate the weighted average
25.81458
```

4. **Return the highest value of x. Return the lowest value of x.**

```
q)x
2012 20 21 4244 3720 999 -203
q)max x
4244
q)min x
-203
```

5. **Sum all the members of x together and calculate the pairwise sums of each element of x.**

```
q)sum x
10813
q)sums x
2012 2032 2053 6297 10017 11016 10813
```

Table

1. **Consider we have a trade table,**

   trade:([]sym:10?`ibm`msft`samsung`hsbc;price:10?302.30;volume:10?4020)

   (a) Select all hsbc trade from the trade table

```
q)trade:([]sym:10?`ibm`msft`samsung`hsbc;price:10?302.30;volume:1
0?4020)
```

```
q)select from trade where sym=`hsbc
sym  price    volume
--------------------
hsbc 0.856576 274
hsbc 32.3438  1485
```

(b) Select all samsung trade where price is greater than 10.

```
q)select from trade where sym=`samsung,price>10.0
sym     price    volume
-----------------------
samsung 284.4499 3530
samsung 127.6378 3996
samsung 232.011  2330
```

(c) Select all trades by sym where price is greater than 50

```
q)select by sym from trade where price>50
sym    | price    volume
-------| ---------------
ibm    | 268.9573 2597
msft   | 267.5842 2644
samsung| 232.011  2330
```

2. Add a new column date into the existing trade table where,

(a) Date column contains only date, i.e., 2013.02.10 and 2013.03.15

```
q)/Consider above example trade table
q)
q)trade:([]sym:10?`ibm`msft`samsung`hsbc;price:10?302.30;volume:1
0?4020)
q)trade
sym     price    volume
-----------------------
msft    149.0894 2956
msft    174.8867 1384
samsung 25.35952 3594
hsbc    59.248   1281
```

```
ibm     113.5554 1882
msft    185.5352 585
samsung 160.062  3162
msft    209.0737 2731
samsung 69.42668 2138
msft    209.1774 2917
q)/Adding date column to the trade table
q)update date:10?(2013.02.10;2013.03.15) from trade
sym     price    volume date
----------------------------------
msft    149.0894 2956   2013.02.10
msft    174.8867 1384   2013.02.10
samsung 25.35952 3594   2013.03.15
hsbc    59.248   1281   2013.02.10
ibm     113.5554 1882   2013.03.15
msft    185.5352 585    2013.02.10
samsung 160.062  3162   2013.03.15
msft    209.0737 2731   2013.03.15
samsung 69.42668 2138   2013.02.10
msft    209.1774 2917   2013.02.10
```

(b) Considering we are loading data from historical database, but we want trades where date should be greater than or equal to 2013.02.10 and should not be more than 2013.03.15

```
q)/ Incase you are dealing with historical db & wants trades
within certain dates

q)select from trade where date within (startingdate; enddate)
```

3. **Calculate the count of all symbols in ascending order within a certain time frame.**

(a) Add the time column to the existing trade table.

```
q)trade:update time:10?.z.T from trade
q)trade
sym     price    volume date       time
-----------------------------------------------
```

```
msft    149.0894 2956   2013.02.10 07:14:12.294
msft    174.8867 1384   2013.02.10 14:37:39.706
samsung 25.35952 3594   2013.03.15 10:22:17.100
hsbc    59.248   1281   2013.02.10 10:51:36.028
ibm     113.5554 1882   2013.02.10 07:46:26.915
msft    185.5352 585    2013.02.10 01:09:50.253
samsung 160.062  3162   2013.02.10 06:16:08.787
msft    209.0737 2731   2013.02.10 02:23:53.831
samsung 69.42668 2138   2013.02.10 17:48:54.238
msft    209.1774 2917   2013.03.15 06:28:56.306
```

(b) **Now calculate the count of all symbols in ascending order within a certain time for date 2013.02.10.**

```
q)`numsym xasc select numsym:count i by sym from trade where time
within (07:14:
12.000;14:00:00.000),date=2013.02.10
sym | numsym
----| ------
hsbc| 1
ibm | 1
msft| 1
```