

# quaternion 2.2.1

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Quaternion Package for GNU Octave

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# Preface

The GNU Octave quaternion package from version 2 onwards was developed by Lukas F. Reichlin with important contributions by Juan Pablo Carbajal. This new package is intended as a replacement for quaternion-1.0.0 by A. Scottedward Hodel. It is loosely based on ideas from the Quaternion Toolbox for Matlab by Steve Sangwine and Nicolas Le Bihan with a special focus on code simplicity and vectorization. Its main features are:

- Matrices and n-dimensional arrays of quaternions.
- Overloaded operators due to the use of classes introduced with Octave 3.2.
- Operator semantics similar to Octave's built-in complex numbers.
- Fully vectorized code for crunching large quaternion arrays in a speedy manner.

## Using the help function

Some functions of the quaternion package are listed with the somewhat cryptic prefix `@quaternion/`. This prefix is only needed to view the help text of the function, e.g. `help norm` shows the built-in function while `help @quaternion/norm` shows the overloaded function for quaternions. Note that there are quaternion functions like `unit` that have no built-in equivalent.

When just using the function, the leading `@quaternion/` must **not** be typed. Octave selects the right function automatically. So one can type `norm (q)` and `norm (matrix)` regardless of the class of the argument.

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# 1 Quaternions

## 1.1 quaternion

`q = quaternion (w)` [Function File]  
`q = quaternion (x, y, z)` [Function File]  
`q = quaternion (w, x, y, z)` [Function File]

Constructor for quaternions - create or convert to quaternion.

$$q = w + x*i + y*j + z*k$$

Arguments  $w$ ,  $x$ ,  $y$  and  $z$  can be scalars, matrices or  $n$ -dimensional arrays, but they must be real-valued and of equal size. If scalar part  $w$  or components  $x$ ,  $y$  and  $z$  of the vector part are not specified, zero matrices of appropriate size are assumed.

### Example

```

octave:1> q = quaternion (2)
q = 2 + 0i + 0j + 0k

octave:2> q = quaternion (3, 4, 5)
q = 0 + 3i + 4j + 5k

octave:3> q = quaternion (2, 3, 4, 5)
q = 2 + 3i + 4j + 5k

octave:4> w = [2, 6, 10; 14, 18, 22];
octave:5> x = [3, 7, 11; 15, 19, 23];
octave:6> y = [4, 8, 12; 16, 20, 24];
octave:7> z = [5, 9, 13; 17, 21, 25];
octave:8> q = quaternion (w, x, y, z)
q.w =
    2     6    10
   14    18    22

q.x =
    3     7    11
   15    19    23

q.y =
    4     8    12
   16    20    24

q.z =
    5     9    13
   17    21    25

octave:9>
  
```

## 1.2 qi

`qi` [Function File]  
 Create x-component of a quaternion's vector part.

$$q = w + x*qi + y*qj + z*qk$$

**Example**

```
octave:1> q1 = quaternion (1, 2, 3, 4)
q1 = 1 + 2i + 3j + 4k
octave:2> q2 = 1 + 2*qi + 3*qj + 4*qk
q2 = 1 + 2i + 3j + 4k
octave:3>
```

**1.3 qj****qj**

[Function File]

Create y-component of a quaternion's vector part.

$$q = w + x*qi + y*qj + z*qk$$

**Example**

```
octave:1> q1 = quaternion (1, 2, 3, 4)
q1 = 1 + 2i + 3j + 4k
octave:2> q2 = 1 + 2*qi + 3*qj + 4*qk
q2 = 1 + 2i + 3j + 4k
octave:3>
```

**1.4 qk****qk**

[Function File]

Create z-component of a quaternion's vector part.

$$q = w + x*qi + y*qj + z*qk$$

**Example**

```
octave:1> q1 = quaternion (1, 2, 3, 4)
q1 = 1 + 2i + 3j + 4k
octave:2> q2 = 1 + 2*qi + 3*qj + 4*qk
q2 = 1 + 2i + 3j + 4k
octave:3>
```

**1.5 q2rot****[axis, angle] = q2rot (q)**

[Function File]

Extract vector/angle form of a unit quaternion  $q$ .**Inputs** $q$  Unit quaternion describing the rotation.**Outputs** $axis$  Eigenaxis as a 3-d unit vector  $[x, y, z]$ . $angle$  Rotation angle in radians. The positive direction is determined by the right-hand rule applied to  $axis$ . The angle lies in the interval  $[0, 2\pi]$ .

**Example**

```

octave:1> axis = [0, 0, 1]
axis =
    0    0    1
octave:2> angle = pi/4
angle = 0.78540
octave:3> q = rot2q (axis, angle)
q = 0.9239 + 0i + 0j + 0.3827k
octave:4> [vv, th] = q2rot (q)
vv =
    0    0    1
th = 0.78540
octave:5> theta = th*180/pi
theta = 45.000
octave:6>

```

**1.6 rot2q** **$q = \text{rot2q}(\text{axis}, \text{angle})$** 

[Function File]

Create unit quaternion  $q$  which describes a rotation of  $\text{angle}$  radians about the vector  $\text{axis}$ . This function uses the active convention where the vector  $\text{axis}$  is rotated by  $\text{angle}$  radians. If the coordinate frame should be rotated by  $\text{angle}$  radians, also called the passive convention, this is equivalent to rotating the  $\text{axis}$  by  $-\text{angle}$  radians.

**Inputs**

$\text{axis}$       Vector  $[x, y, z]$  describing the axis of rotation.

$\text{angle}$       Rotation angle in radians. The positive direction is determined by the right-hand rule applied to  $\text{axis}$ .

**Outputs**

$q$       Unit quaternion describing the rotation.

**Example**

```

octave:1> axis = [0, 0, 1];
octave:2> angle = pi/4;
octave:3> q = rot2q (axis, angle)
q = 0.9239 + 0i + 0j + 0.3827k
octave:4> v = quaternion (1, 1, 0)
v = 0 + 1i + 1j + 0k
octave:5> vr = q * v * conj (q)
vr = 0 + 0i + 1.414j + 0k
octave:6>

```



## 2 Quaternion Methods

### 2.1 @quaternion/abs

`qabs = abs (q)` [Function File]  
 Modulus of a quaternion.

$$q = w + x*i + y*j + z*k$$

$$\text{abs} (q) = \sqrt{w.^2 + x.^2 + y.^2 + z.^2}$$

### 2.2 @quaternion/arg

`theta = arg (q)` [Function File]  
 Compute the argument or phase of quaternion  $q$  in radians.  $theta$  is defined as `atan2 (sqrt (q.x.^2 + q.y.^2 + q.z.^2), q.w)`. The argument  $theta$  lies in the range  $(0, \pi)$ .

### 2.3 @quaternion/blkdiag

`q = blkdiag (q1, q2, ...)` [Function File]  
 Block-diagonal concatenation of quaternions.

### 2.4 @quaternion/cast

`q = cast (q, 'type')` [Function File]  
 Convert the components of quaternion  $q$  to data type  $type$ . Valid types are int8, uint8, int16, uint16, int32, uint32, int64, uint64, double, single and logical.

### 2.5 @quaternion/cat

`q = cat (dim, q1, q2, ...)` [Function File]  
 Concatenation of quaternions along dimension  $dim$ .

### 2.6 @quaternion/ceil

`q = ceil (q)` [Function File]  
 Round quaternion  $q$  towards positive infinity.

### 2.7 @quaternion/columns

`nc = columns (q)` [Function File]  
 Return number of columns  $nc$  of quaternion array  $q$ .

### 2.8 @quaternion/conj

`q = conj (q)` [Function File]  
 Return conjugate of a quaternion.

$$q = w + x*i + y*j + z*k$$

$$\text{conj} (q) = w - x*i - y*j - z*k$$

## 2.9 @quaternion/cumsum

`q = cumsum (q)` [Function File]  
`q = cumsum (q, dim)` [Function File]  
`q = cumsum (... , 'native')` [Function File]  
`q = cumsum (... , 'double')` [Function File]  
`q = cumsum (... , 'extra')` [Function File]

Cumulative sum of elements along dimension *dim*. If *dim* is omitted, it defaults to the first non-singleton dimension. See `help cumsum` for more information.

## 2.10 @quaternion/diag

`q = diag (v)` [Function File]  
`q = diag (v, k)` [Function File]

Return a diagonal quaternion matrix with quaternion vector *V* on diagonal *K*. The second argument is optional. If it is positive, the vector is placed on the *K*-th super-diagonal. If it is negative, it is placed on the *-K*-th sub-diagonal. The default value of *K* is 0, and the vector is placed on the main diagonal. Given a matrix argument, instead of a vector, `diag` extracts the *K*-th diagonal of the matrix.

## 2.11 @quaternion/diff

`qdot = diff (q, omega)` [Function File]

Derivative of a quaternion.

Let *Q* be a quaternion to transform a vector from a fixed frame to a rotating frame. If the rotating frame is rotating about the [x, y, z] axes at angular rates [wx, wy, wz], then the derivative of *Q* is given by

$$Q' = \text{diff}(Q, \omega)$$

If the passive convention is used (rotate the frame, not the vector), then

$$Q' = \text{diff}(Q, -\omega)$$

## 2.12 @quaternion/exp

`qexp = exp (q)` [Function File]

Exponential of a quaternion.

## 2.13 @quaternion/fix

`q = fix (q)` [Function File]

Round quaternion *q* towards zero.

## 2.14 @quaternion/floor

`q = floor (q)` [Function File]

Round quaternion *q* towards negative infinity.

## 2.15 @quaternion/full

`fq = full (sq)` [Function File]

Return a full storage quaternion representation *fq* from sparse or diagonal quaternion *sq*.

## 2.16 @quaternion/get

`get (q)` [Function File]  
`value = get (q, "key")` [Function File]  
`[val1, val2, ...] = get (q, "key1", "key2", ...)` [Function File]  
 Access key values of quaternion objects.

### Keys

`w` Return scalar part  $w$  of quaternion  $q$  as a built-in type.  
`x, y, z` Return component  $x$ ,  $y$  or  $z$  of the vector part of quaternion  $q$  as a built-in type.  
`s` Return scalar part of quaternion  $q$ . The vector part of  $q$  is set to zero.  
`v` Return vector part of quaternion  $q$ . The scalar part of  $q$  is set to zero.

## 2.17 @quaternion/inv

`qinv = inv (q)` [Function File]  
 Return inverse of a quaternion.

## 2.18 @quaternion/isempty

`bool = isempty (q)` [Function File]  
 Return true if quaternion  $q$  is empty and false otherwise.

## 2.19 @quaternion/isfinite

`bool = isfinite (q)` [Function File]  
 Return a logical array which is true where the elements of  $q$  are finite values and false where they are not.

## 2.20 @quaternion/isinf

`bool = isinf (q)` [Function File]  
 Return a logical array which is true where the elements of  $q$  are infinite and false where they are not.

## 2.21 @quaternion/isnan

`bool = isnan (q)` [Function File]  
 Return a logical array which is true where the elements of  $q$  are NaN values and false where they are not.

## 2.22 @quaternion/ispure

`bool = ispure (q)` [Function File]  
 Return true if scalar part of quaternion is zero, otherwise return false.

## 2.23 @quaternion/isreal

`bool = isreal (q)` [Function File]  
 Return true if the vector part of quaternion  $q$  is zero and false otherwise.

## 2.24 @quaternion/length

`l = length (q)` [Function File]  
 Return the "length"  $l$  of the quaternion array  $q$ . For quaternion matrices, the length is the number of rows or columns, whichever is greater (this odd definition is used for compatibility with MATLAB).

## 2.25 @quaternion/log

`qlong = log (q)` [Function File]  
 Logarithmus naturalis of a quaternion.

## 2.26 @quaternion/ndims

`n = ndims (q)` [Function File]  
 Return the number of dimensions of quaternion  $q$ . For any array, the result will always be larger than or equal to 2. Trailing singleton dimensions are not counted.

## 2.27 @quaternion/norm

`n = norm (q)` [Function File]  
 Norm of a quaternion.

## 2.28 @quaternion/reshape

`q = reshape (q, m, n, ...)` [Function File]  
`q = reshape (q, [m n ...])` [Function File]  
`q = reshape (q, ..., [], ...)` [Function File]  
`q = reshape (q, size)` [Function File]  
 Return a quaternion array with the specified dimensions  $(m, n, \dots)$  whose elements are taken from the quaternion array  $q$ . The elements of the quaternion are accessed in column-major order (like Fortran arrays are stored).

## 2.29 @quaternion/round

`q = round (q)` [Function File]  
 Round the components of quaternion  $q$  towards the nearest integers.

## 2.30 @quaternion/rows

`nr = rows (q)` [Function File]  
 Return number of rows  $nr$  of quaternion array  $q$ .

## 2.31 @quaternion/set

`set (q)` [Function File]  
`set (q, "key", value, ...)` [Function File]  
`qret = set (q, "key", value, ...)` [Function File]  
 Set or modify properties of quaternion objects. If no return argument  $qret$  is specified, the modified quaternion object is stored in input argument  $q$ . `set` can handle multiple keys in one call: `set (q, 'key1', val1, 'key2', val2, 'key3', val3)`. `set (q)` prints a list of the object's key names.

**Keys**

<i>w</i>	Assign real-valued array <i>val</i> to scalar part <i>w</i> of quaternion <i>q</i> .
<i>x, y, z</i>	Assign real-valued array <i>val</i> to component <i>x, y</i> or <i>z</i> of the vector part of quaternion <i>q</i> .
<i>s</i>	Assign scalar part of quaternion <i>val</i> to scalar part of quaternion <i>q</i> . The vector part of <i>q</i> is left untouched.
<i>v</i>	Assign vector part of quaternion <i>val</i> to vector part of quaternion <i>q</i> . The scalar part of <i>q</i> is left untouched.

## 2.32 @quaternion/size

`nvec = size (q)` [Function File]  
`n = size (q, dim)` [Function File]  
`[nx, ny, ...] = size (q)` [Function File]  
 Return size of quaternion arrays.

### Inputs

<i>q</i>	Quaternion object.
<i>dim</i>	If given a second argument, <b>size</b> will return the size of the corresponding dimension.

### Outputs

<i>nvec</i>	Row vector. The first element is the number of rows and the second element the number of columns. If <i>q</i> is an <i>n</i> -dimensional array of quaternions, the <i>n</i> -th element of <i>nvec</i> corresponds to the size of the <i>n</i> -th dimension of <i>q</i> .
<i>n</i>	Scalar value. The size of the dimension <i>dim</i> .
<i>nx</i>	Number of rows.
<i>ny</i>	Number of columns.
<i>...</i>	Sizes of the 3rd to <i>n</i> -th dimensions.

## 2.33 @quaternion/size\_equal

`bool = size_equal (a, b, ...)` [Function File]  
 Return true if quaternions (and matrices) *a, b, ...* are of equal size and false otherwise.

## 2.34 @quaternion/sparse

`sq = sparse (fq)` [Function File]  
 Return a sparse quaternion representation *sq* from full quaternion *fq*.

## 2.35 @quaternion/squeeze

`qret = squeeze (q)` [Function File]  
 Remove singleton dimensions from quaternion *q* and return the result. Note that for compatibility with MATLAB, all objects have a minimum of two dimensions and row vectors are left unchanged.

## 2.36 @quaternion/sum

```

q = sum (q) [Function File]
q = sum (q, dim) [Function File]
q = sum (... , 'native') [Function File]
q = sum (... , 'double') [Function File]
q = sum (... , 'extra') [Function File]

```

Sum of elements along dimension *dim*. If *dim* is omitted, it defaults to the first non-singleton dimension. See `help sum` for more information.

## 2.37 @quaternion/tril

```

q = tril (q) [Function File]
q = tril (q, k) [Function File]
q = tril (q, k, 'pack') [Function File]

```

Return a new quaternion matrix formed by extracting the lower triangular part of the quaternion *q*, and setting all other elements to zero. The second argument *k* is optional, and specifies how many diagonals above or below the main diagonal should also be included. Default value for *k* is zero. If the option "pack" is given as third argument, the extracted elements are not inserted into a matrix, but rather stacked column-wise one above other.

## 2.38 @quaternion/triu

```

q = triu (q) [Function File]
q = triu (q, k) [Function File]
q = triu (q, k, 'pack') [Function File]

```

Return a new quaternion matrix formed by extracting the upper triangular part of the quaternion *q*, and setting all other elements to zero. The second argument *k* is optional, and specifies how many diagonals above or below the main diagonal should also be included. Default value for *k* is zero. If the option "pack" is given as third argument, the extracted elements are not inserted into a matrix, but rather stacked column-wise one above other.

## 2.39 @quaternion/unit

```

qn = unit (q) [Function File]

```

Normalize quaternion to length 1 (unit quaternion).

```

q = w + x*i + y*j + z*k
unit (q) = q ./ sqrt (w.^2 + x.^2 + y.^2 + z.^2)

```

## 3 Overloaded Quaternion Operators

### 3.1 @quaternion/ctranspose

Conjugate transpose of a quaternion. Used by Octave for "q'".

### 3.2 @quaternion/end

End indexing for quaternions. Used by Octave for "q(1:end)".

### 3.3 @quaternion/eq

Equal to operator for two quaternions. Used by Octave for "q1 == q2".

### 3.4 @quaternion/ge

Greater-than-or-equal-to operator for two quaternions. Used by Octave for "q1 >= q2". The ordering is lexicographic.

### 3.5 @quaternion/gt

Greater-than operator for two quaternions. Used by Octave for "q1 > q2". The ordering is lexicographic.

### 3.6 @quaternion/horzcat

Horizontal concatenation of quaternions. Used by Octave for "[q1, q2]".

### 3.7 @quaternion/ldivide

Element-wise left division for quaternions. Used by Octave for "q1 ./ q2".

### 3.8 @quaternion/le

Less-than-or-equal-to operator for two quaternions. Used by Octave for "q1 <= q2". The ordering is lexicographic.

### 3.9 @quaternion/lt

Less-than operator for two quaternions. Used by Octave for "q1 < q2". The ordering is lexicographic.

### 3.10 @quaternion/minus

Subtraction of two quaternions. Used by Octave for "q1 - q2".

### 3.11 @quaternion/mldivide

Matrix left division for quaternions. Used by Octave for "q1 \ q2".

### 3.12 @quaternion/mpower

Matrix power operator of quaternions. Used by Octave for "q^x".

### 3.13 @quaternion/mrdivide

Matrix right division for quaternions. Used by Octave for " $q_1 / q_2$ ".

### 3.14 @quaternion/mtimes

Matrix multiplication of two quaternions. Used by Octave for " $q_1 * q_2$ ".

### 3.15 @quaternion/ne

Not-equal-to operator for two quaternions. Used by Octave for " $q_1 \neq q_2$ ".

### 3.16 @quaternion/plus

Addition of two quaternions. Used by Octave for " $q_1 + q_2$ ".

### 3.17 @quaternion/power

Power operator of quaternions. Used by Octave for " $q.^x$ ". Exponent  $x$  can be scalar or of appropriate size.

### 3.18 @quaternion/rdivide

Element-wise right division for quaternions. Used by Octave for " $q_1 ./ q_2$ ".

### 3.19 @quaternion/subsasgn

Subscripted assignment for quaternions. Used by Octave for " $q.\text{key} = \text{value}$ ".

#### Subscripts

- $q.w$             Assign real-valued array  $val$  to scalar part  $w$  of quaternion  $q$ .
- $q.x, q.y, q.z$             Assign real-valued array  $val$  to component  $x, y$  or  $z$  of the vector part of quaternion  $q$ .
- $q.s$             Assign scalar part of quaternion  $val$  to scalar part of quaternion  $q$ . The vector part of  $q$  is left untouched.
- $q.v$             Assign vector part of quaternion  $val$  to vector part of quaternion  $q$ . The scalar part of  $q$  is left untouched.
- $q(\dots)$             Assign  $val$  to certain elements of quaternion array  $q$ , e.g.  $q(3, 2:\text{end}) = val$ .

### 3.20 @quaternion/subsref

Subscripted reference for quaternions. Used by Octave for " $q.w$ ".

#### Subscripts

- $q.w$             Return scalar part  $w$  of quaternion  $q$  as a built-in type.
- $q.x, q.y, q.z$             Return component  $x, y$  or  $z$  of the vector part of quaternion  $q$  as a built-in type.
- $q.s$             Return scalar part of quaternion  $q$ . The vector part of  $q$  is set to zero.
- $q.v$             Return vector part of quaternion  $q$ . The scalar part of  $q$  is set to zero.
- $q(\dots)$             Extract certain elements of quaternion array  $q$ , e.g.  $q(3, 2:\text{end})$ .



### 3.21 @quaternion/times

Element-wise multiplication of two quaternions. Used by Octave for " $q1 .* q2$ ".

### 3.22 @quaternion/transpose

Transpose of a quaternion. Used by Octave for " $q.'$ ".

### 3.23 @quaternion/uminus

Unary minus of a quaternion. Used by Octave for " $-q$ ".

### 3.24 @quaternion/uplus

Unary plus of a quaternion. Used by Octave for " $+q$ ".

### 3.25 @quaternion/vertcat

Vertical concatenation of quaternions. Used by Octave for " $[q1; q2]$ ".



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