matrixclass

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```
a=vector([1,2,3])
```

```
a=vector([1,2,3])
```

```
a
```

```
    (1, 2, 3)
```

```
v=vector(QQ,[1,2,3])
```

```
v
```

```
    (1, 2, 3)
```

```
r=VectorSpace(QQ,3)
```

```
p=r([1,2,3])
```

```
p
```

```
    (1, 2, 3)
```

```
p[1]
```

```
    2
```

```
p[2]=12
```

```
p
```

```
    (1, 2, 12)
```

```
p[1:2]
```

```
    (2)
```

```
len(p)
```

```
    3
```

```
r=vector([4,5,6])
```

```
p+r
```

```
    (5, 7, 18)
```

```
var('a b')
a*p+b*r
```

```
    (a + 4*b, 2*a + 5*b, 12*a + 6*b)
```

```
6*p
```

```
    (6, 12, 72)
```

```
p*r
```

```
    86
```

```
p.dot_product(r)
```

```
    86
```

```
p.inner_product(r)
```

```
    86
```

```
p.cross_product(r)
```

```
    (-48, 42, -3)
```

```
p.pairwise_product(r)
```

```
    (4, 10, 72)
```

```
p
```

```
    (1, 2, 12)
```

```
r
```

```
    (4, 5, 6)
```

```
v=vector([1,2,3])
```

```
v.norm()
```

```
    sqrt(14)
```

```
v.norm(1)
```

```
    6
```

```
v.norm(Infinity)
```

```
    3
```

```
v.norm(4)
```

```
    98^(1/4)
```

```
v.parent()
```

```
    Ambient free module of rank 3 over the principal ideal domain Intege
    Ring
```

```
matrix([p,r,v])
```

```
    [ 1  2 12]
    [ 4  5  6]
    [ 1  2  3]
```

```
matrix([[1,2,3],[4,5,6],[7,8,9]])
```

```
    [1 2 3]
    [4 5 6]
    [7 8 9]
```

```
matrix(3,[2,6,4,1,2,3,4,5,6,7,8,9])
```

```
    [2 6 4 1]
    [2 3 4 5]
    [6 7 8 9]
```

```
m=MatrixSpace(QQ,3,4)
```

```
a=m([1,2,3,4,5,6,7,8,9,10,11,12])
```

```
a
```

```
[ 1  2  3  4]
[ 5  6  7  8]
[ 9 10 11 12]
```

```
var('x y z')
x=1
y=2
z=3
w=matrix(SR,[[x+y,x^2],[x+1,2]])
```

```
w*w
```

```
[11  5]
[10  6]
```

```
w
```

```
[3 1]
[2 2]
```

```
r=PolynomialRing(QQ,9,'x')
a=matrix(r,3,3,r.gens())
```

```
a
```

```
[x0 x1 x2]
[x3 x4 x5]
[x6 x7 x8]
```

```
a*a
```

```
[ x0^2 + x1*x3 + x2*x6 x0*x1 + x1*x4 + x2*x7 x0*x2 + x1*x5 + x2*x8]
[x0*x3 + x3*x4 + x5*x6  x1*x3 + x4^2 + x5*x7 x2*x3 + x4*x5 + x5*x8]
[x0*x6 + x3*x7 + x6*x8 x1*x6 + x4*x7 + x7*x8  x2*x6 + x5*x7 + x8^2]
```

```
det(a)
```

```
-x2*x4*x6 + x1*x5*x6 + x2*x3*x7 - x0*x5*x7 - x1*x3*x8 + x0*x4*x8
```

```
matrix(QQ,2,3,lambda i,j:v[i]/v[(j)])
```

```
[  1 1/2 1/3]
[  2   1 2/3]
```

```
vector([2,3,5]
```

```
Traceback (click to the left of this block for traceback)
...
SyntaxError: invalid syntax
```

```
q=matrix(20,80,{(0,1):2,(5,4):5})
```

```
show(q)
```

0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

```
q[7,12]
```

```
0
```

```
matrix(2,3,5)
```

```
Traceback (click to the left of this block for traceback)
...
TypeError: nonzero scalar matrix must be square
```

```
matrix(2,3)
```

```
[0 0 0]
[0 0 0]
```

```
a=diagonal_matrix([1,2,3])
a
```

```
[1 0 0]
[0 2 0]
[0 0 3]
```

```
jordan_block(-2,3)
```

```
[-2  1  0]
[ 0 -2  1]
[ 0  0 -2]
```

```
f=identity_matrix(6)
```

```
f
```

```
[1 0 0 0 0 0]
[0 1 0 0 0 0]
[0 0 1 0 0 0]
[0 0 0 1 0 0]
[0 0 0 0 1 0]
[0 0 0 0 0 1]
```

```
l=matrix(1,1,[4])
k=matrix(2,2,[1,2,3,4])
p=block_matrix([[l,0],[0,k]],subdivide=False)
```

```
p
```

```
[4 0 0]
[0 1 2]
[0 3 4]
```

```
show(p)
```

$$\left(\begin{array}{cc|cc} 4 & 5 & 0 & 0 \\ 6 & 7 & 0 & 0 \\ \hline 1 & 2 & 1 & 0 \\ 3 & 4 & 0 & 1 \end{array}\right)$$

```
p
```

```
[4|0 0]
[-+---]
[0|1 2]
[0|3 4]
```

```
b=matrix(QQ,2,3,range(6))
```

```
b
```

```
[0 1 2]
[3 4 5]
```

```
block_matrix([[k,b],[b,k]],subdivide=False)
```

```
[1 2 0 1 2]
[3 4 3 4 5]
[0 1 2 1 2]
[3 4 5 3 4]
```

```
a
```

```
[1 0 0]
[0 2 0]
[0 0 3]
```

```
a=matrix(3,3,[1,2,3,4,5,6,7,8,9])
```

```
a
```

```
[1 2 3]
[4 5 6]
[7 8 9]
```

```
a[1,2]
```

```
6
```

```
a[1]
```

```
(4, 5, 6)
```

```
a.row(1)
```

```
(4, 5, 6)
```

```
a[:,1]
```

```
[2]
[5]
[8]
```

```
a[1:3,1:3]
```

```
[5 6]
[8 9]
```

```
a.list()
```

```
[1, 2, 3, 4, 5, 6, 7, 8, 9]
```

```
a.matrix_from_columns([0,2,1])
```

```
[1 3 2]
[4 6 5]
[7 9 8]
```

```
a
```

```
[1 2 3]
[4 5 6]
[7 8 9]
```

```
a.columns()
```

```
[(1, 4, 7), (2, 5, 8), (3, 6, 9)]
```

```
a.submatrix(1,1,2,1)
```

```
[5]
[8]
```

```
a
```

```
[1 2 3]
[4 5 6]
[7 8 9]
```

```
a.swap_rows(0,1)
```

```
a
```

```
[4 5 6]
[1 2 3]
[7 8 9]
```

```
a.rescale_row(1,2)
```

```
a
```

```
[4 5 6]
[2 4 6]
[7 8 9]
```

```
a.add_multiple_of_row(0,1,3)
```

```
a
```

```
[10 17 24]
[ 2  4  6]
[ 7  8  9]
```

```
a.stack(b)
```

```
[10 17 24]
[ 2  4  6]
[ 7  8  9]
[ 1  2  3]
[ 4  5  6]
[ 7  8  9]
```

```
b=matrix(2,2,[1,2,3,4])
```

```
a.block_sum(b)
```

```
[10 17 24  0  0]
[ 2  4  6  0  0]
[ 7  8  9  0  0]
[ 0  0  0  1  2]
[ 0  0  0  3  4]
```

```
a.tensor_product(b)
```

```
[10 20|17 34|24 48]
[30 40|51 68|72 96]
[-----+-----+-----]
[ 2  4| 4  8| 6 12]
[ 6  8|12 16|18 24]
[-----+-----+-----]
[ 7 14| 8 16| 9 18]
[21 28|24 32|27 36]
```

```
a.rank()
```

```
2
```

```
a
```

```
[10 17 24]
[ 2  4  6]
[ 7  8  9]
```

```
a.determinant()
```

```
0
```

```
a.det()
```

```
0
```

```
a.trace()
```

```
23
```

```
a=vector([1,2,3])
```

```
a=matrix(2,2,[1,2,3,4])
```

```
a.inverse()
```

```
[  -2    1]
[ 3/2 -1/2]
```

```
a^-1
```

```
[  -2    1]
[ 3/2 -1/2]
```

```
~a
```

```
[  -2    1]
[ 3/2 -1/2]
```

```
a=matrix(3,3,[1,2,3,4,5,6,7,8,9])
```

```
a^-1
```

```
    Traceback (click to the left of this block for traceback)
    ...
    ZeroDivisionError: Matrix is singular
```

```
a.transpose()
```

```
    [1 4 7]
    [2 5 8]
    [3 6 9]
```

```
a
```

```
    [1 2 3]
    [4 5 6]
    [7 8 9]
```

```
a.antitranspose()
```

```
    [9 6 3]
    [8 5 2]
    [7 4 1]
```

```
b=matrix(2,2,[2*i,3,4,7*i])
```

```
c=b.conjugate()
```

```
b*c
```

```
    [   16 -15*I]
    [ 20*I    61]
```

```
b
```

```
    [2*I   3]
    [  4 7*I]
```

```
c
```

```
    [-2*I    3]
    [   4 -7*I]
```

```
b.conjugate_transpose()
```

```
    [-2*I    4]
    [   3 -7*I]
```

```
a.adjoint()
```

```
[ -3   6  -3]
[  6 -12   6]
[ -3   6  -3]
```

```
a.permanent()
```

```
450
```

```
v=vector([1,2,3])
```

```
a.iterates(v,6)
```

```
[      1       2       3]
[     30      36      42]
[    468     576     684]
[   7560    9288   11016]
[ 121824  149688  177552]
[1963440 2412504 2861568]
```

```
y=matrix(2,2,[1,2,2,4])
```

```
det(y)
```

```
0
```

```
u=vector([2,3])
```

```
x=y.solve_right(u)
```

```
Traceback (click to the left of this block for traceback)
...
ValueError: matrix equation has no solutions
```

```

```

```
(2, 0)
```

```
solve_right?
```

```
No object 'solve_right' currently defined.
```

```
s=matrix(2,2,[1,3,3,1])
```

```
s.eigenvalues()
```

```
[4, -2]
```

```
show(s.eigenvectors_left())
```

$$[(4, [(1, 1)], 1), (-2, [(1, -1)], 1)]$$

```
show(s.eigenmatrix_left())
```

$$\left(\begin{pmatrix} 4 & 0 \\ 0 & -2 \end{pmatrix}, \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}\right)$$

```
(aa,bb)=s.eigenmatrix_left()
```

```
bb
```

```
[ 1  1]
[ 1 -1]
```

```
bb[0]
```

```
(1, 1)
```

```
s.charpoly('t')
```

```
t^2 - 2*t - 8
```

```
s.fcp()
```

```
(x - 4) * (x + 2)
```

```
f(x)=s.minpoly()
```

```
f(-2)
```

```
0
```

```
f(x)
```

```
(x - 2)*x - 8
```

```
s.jordan_form(transformation=true)
```

```
(
[ 4| 0]
[--+--]  [ 1  1]
[ 0|-2], [ 1 -1]
)
```

```
s.smith_form()
```

```
(
[1 0]  [ 0  1]  [ 0 -1]
[0 8], [ 1 -3], [ 1  3]
)
```

```
s.gram_schmidt()
```

```
(
[   1    3]  [  1   0]
[12/5 -4/5], [3/5   1]
)
```

```
show(s.LU())
```

$$\left(\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ \frac{1}{3} & 1 \end{pmatrix}, \begin{pmatrix} 3 & 1 \\ 0 & \frac{8}{3} \end{pmatrix}\right)$$

```
s.parent()
```

```
Full MatrixSpace of 2 by 2 dense matrices over Integer Ring
```

```
(a,b,c)=s.LU()
```

```
c.parent()
```

```
Full MatrixSpace of 2 by 2 dense matrices over Rational Field
```

```
s=matrix(RDF,3,3,[1,2,3,4,5,6,7,8,9])
```

```
show(s.SVD())
```

$$\left(\begin{pmatrix} -0.214837238368 & 0.887230688346 & 0.408248290464 \\ -0.520587389465 & 0.249643952988 & -0.816496580928 \\ -0.826337540561 & -0.38794278237 & 0.408248290464 \end{pmatrix}, \begin{pmatrix} 16.8481033526 & (\\ 0.0 & 1.068369514 \\ 0.0 & (\end{pmatrix}\right.$$

```
s.QR()
```

```
(
[0.12309149097933259  0.9045340337332906  0.4082482904638648]
[  0.492365963917331  0.3015113445777647 -0.8164965809277258]
[ 0.8616404368553293 -0.3015113445777646 0.40824829046386246],

[     8.124038404635959      9.601136296387956     11.0782341881399
[                  -0.0     0.9045340337332883     1.809068067466580
[                  -0.0                   -0.0 2.10020802832167060-1
)
```

```
s.schur()
```

```
(
[ -0.231970687246286  -0.882905959653586 0.40824829046386263]  [
16.116843969807043       4.898979485566356  1.3110979072920493e-15]
[-0.5253220933012336 -0.2395204200542056 -0.8164965809277261]  [
0.0      -1.116843969807043  -4.873580987698998e-16]
[-0.8186734993561817  0.4038651195451737 0.40824829046386313], [
0.0                    0.0 -2.9480554563915386e-16]
)
```

```
s.rational_form()
```

```
[ 0  0  0]
[ 1  0 18]
[ 0  1 15]
```

```
s=matrix(QQ,3,3,[1,2,3,4,5,6,7,8,9])
```

```
s.symplectic_form()
```

```
Traceback (click to the left of this block for traceback)
...
ValueError: Can only find symplectic bases for anti-symmetric matric
```

```
s.hessenberg_form()
```

```
[    1  29/4     3]
[    4  31/2     6]
[    0 -27/8  -3/2]
```

```
s
```

```
[1 2 3]
[4 5 6]
[7 8 9]
```

```
s.is_zero()
```
```
False
```

```
s.is_symmetric()
```
```
False
```

```
s.is_square()
```
```
True
```

```
s.is_unitary()
```
```
False
```

```
s.is_singular()
```
```
True
```

```
s.is_one()
```
```
False
```

```
m=MatrixSpace(QQ,10,sparse=true)
```

```
a=m.random_element(density=0.5)
```

```
a
```
```
[    0     0     0     0   1/2     0    -1    -4     0     0]
[    0  2/13    -2  -1/2 -1/42    -9     0   1/9     0     0]
[    0     2     0 -1/53     0     0     0     0     0     0]
[    0    -3     0   1/2     0     0     0    -1     0  -1/2]
[-1/71     0     0     0    -2    -1     0     0    -1   3/4]
[    1     0   7/3     0     0     5     0     1     0     0]
[    0     0     6     0     0     0     0  -1/7  -1/2     0]
[ -1/2     0     0     0     0     0     4     0     0   1/2]
[    0     0    -3     0     0     0     0    -4     0     0]
[    0 53/24  -1/2  -1/2     0    -4     0  -1/2   1/2     0]
```

```
a.is_sparse()
```
```
True
```

```
a.density()
```
```
37/100
```

```
m=matrix(ZZ,3,3,[1,1,1,1,1,1,1,1,1],sparse=true)
```

```
m
```

```
[1 1 1]
[1 1 1]
[1 1 1]
```

```
m.is_sparse()
```

```
True
```

```
m.sparse_matrix()
```

```
[1 1 1]
[1 1 1]
[1 1 1]
```

```
s=matrix(ZZ,3,3,[1,2,3,4,5,6,7,8,9])
```

```
s.is_sparse()
```

```
False
```

```
s=matrix(ZZ,3,3,[0,0,0,0,0,0,0,0,0])
```

```
s.is_sparse()
```

```
False
```

```
```