Q3 TUTORIAL

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Quantum Many-Body Systems with Q3

Fock is a Mathematica package to help study quantum many-body systems. It provides various tools and utilities for symbolic and numerical calculations to simulate quantum many-body systems.

Fermion	Represents fermionic operators
Majorana	Represents operators for Majorana fermions
Boson	Represents bosonic operators
Heisenberg	Represents operators satisfying the Heisenberg canonical commutation relations

Species involved in the study of quantum many-body systems.

You first need to load the package.

In[1]:=
```
<< Q3`
```

Let us consider a system of fermions. Choose a symbol, here **c**, to denote the fermions.

In[2]:=
```
Let[Fermion, c]
```

Here is an example of the non-commutative multiplication of fermion operators.

In[3]:=
```
c[1] ** c[2]
```

Out[3]= $-c_2\, c_1$

Ket[] returns the Vacuum state.

In[4]:=
```
v1 = Ket[]
```

Out[4]= $\left|\_\right\rangle$

In[5]:=
```
v1 // InputForm
```

Out[5]//InputForm=
```
Ket[<||>]
```

The Fermion operators act on the state vectors.

In[6]:=
```
v2 = Dagger[c[1]] ** Dagger[c[2]] ** Ket[]
```

Out[6]= $\left|1_{c_1} 1_{c_2}\right\rangle$

Hamiltonians are written in terms of Fermion operators.

In[7]:=
```
op = Q[c[1], c[2]] + t PlusDagger@FockHopping[c[1], c[2]]
```

Out[7]= $c_1^\dagger c_1 + t\left(c_1^\dagger c_2 + c_2^\dagger c_1\right) + c_2^\dagger c_2$

Its matrix representation in the standard basis can be obtained by means of Matrix .

In[8]:=
```
mat = Matrix[op];
mat // MatrixForm
```

Out[8]//MatrixForm=

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & t & 0 \\ 0 & t & 1 & 0 \\ 0 & 0 & 0 & 2 \end{pmatrix}$$

Now consider a Boson operator.

In[1]:=
```
Let[Boson, a]
```

In[2]:=
```
op = Hop[a@{1, 2, 3}];
op = PlusDagger[op]
```

Out[2]= $a_1^\dagger a_2 + a_2^\dagger a_1 + a_2^\dagger a_3 + a_3^\dagger a_2$

In[3]:=
```
ket = Dagger[a[1]] ** Ket[]
```

Out[3]= $\left|1_{a_1}\right\rangle$

In[4]:=
```
op ** ket
```

Out[4]= $\left|1_{a_2}\right\rangle$

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- Quantum Many-Body Systems

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