Q3 TUTORIAL

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Q3: Quick Start

- Quantum Computation and Information
- Quantum Spin Systems
- Quantum Many–Body Systems

Q3 is a Mathematica application to help study quantum information processing, quantum many-body systems, and quantum spin systems. It provides various tools and utilities for symbolic and numerical calculations in these areas of quantum physics.

The first thing is to load the Q3 package.

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

Quantum Computation and Information

Q3 provides many functions for studying quantum information processing.

First, choose a symbol to use to refer to the set of qubits. For example, choose `S`, and declare it to be a qubit using Let.

```
In[3]:= Let[Qubit, S]
```

The following expression involves two qubits `S[1,None]` and `S[2,None]`. The final index denotes different Pauli operators acting on the qubit. For example, `S[1,3]` means the Pauli Z acting on `S[1,None]`.

```
In[4]:= op = S[1, 3] ** S[2, 1]
```

Out[4]= $S_1^z S_2^x$

The logical state vector can be denoted by Ket [<|...|>]. As in many functions in Quisso, one can skip the final None for each qubit -- it is added automatically.

```
In[5]:= Ket[S[1, None] → 1, S[2, None] → 1]
        Ket[S[1] → 1, S[2] → 1]
```

Out[5]= $\left|1_{S_1} 1_{S_2}\right\rangle$

Out[6]= $\left|1_{S_1} 1_{S_2}\right\rangle$

```
In[7]:= ket = Ket[] + 3 Ket[S[1] → 1, S[2] → 1, S[3] → 1]
```

Out[7]= $\left|\text{␣}\right\rangle + 3 \left|1_{S_1} 1_{S_2} 1_{S_3}\right\rangle$

In this case, you do no have to worry about the number of spins in the operator and the state vector. Different qubits are distinguished by the symbol and the flavor indices (excluding the final index).

```
In[8]:= new = op ** ket
        new // LogicalForm
```

Out[8]= $-3 \left|1_{S_1} 1_{S_3}\right\rangle + \left|1_{S_2}\right\rangle$

Out[9]= $\left|0_{S_1} 1_{S_2} 0_{S_3}\right\rangle - 3 \left|1_{S_1} 0_{S_2} 1_{S_3}\right\rangle$

Quantum Many-Body Systems

Q3 is also useful to study quantum many-body systems.

Choose a symbol to denote various species of Fermions.

In[42]:=
```
Let[Fermion, c]
```

In[43]:=
```
expr = c[1] ** Dagger[c[1]] ** c[2] ** Dagger[c[2]] + Dagger[c[2]] ** c[2]
```

Out[43]=

$1 - c_1^\dagger c_1 + c_1^\dagger c_2^\dagger c_2 c_1$

In[44]:=
```
bs = FermionBasis[c@{1, 2}, 3];
bs // LogicalForm
```

Out[45]=

$\{ |0_{c_1} 0_{c_2}\rangle, |1_{c_1} 0_{c_2}\rangle, |0_{c_1} 1_{c_2}\rangle, |1_{c_1} 1_{c_2}\rangle \}$

In[46]:=
```
expr ** bs
```

Out[46]=

$\{ |\text{␣}\rangle, 0, |1_{c_2}\rangle, |1_{c_1} 1_{c_2}\rangle \}$

Quantum Spin Systems

You can study quantum spin systems with Q3 as well.

Choose a symbol to use to denote different spins.

In[47]:=
```
Let[Spin, J]
```

Here are two spin angular momentum operators acting on two spins `S[1,None]` and `S[2,None]`, respectively.

In[48]:=
```
op = J[1, 3] ** J[2, 2]
```

Out[48]=

$J_1^z J_2^y$

In[54]:=
```
op ** (Ket[] + I * Ket[J@{1, 2} -> -1 / 2])
```

Out[54]=

$$-\frac{1}{4} \left| -\frac{1}{2}_{J_1} \right\rangle + \frac{1}{4} i \left| -\frac{1}{2}_{J_2} \right\rangle$$

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- Q3

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