Cargar el paquete

In[1]:=

```
Needs["qm`Dirac`"]
```

The qm add-on qm`Dirac` version BETA
7/May/2017 has been loaded today Sun 7 May 2017 12:07:57
Mathematica 11.0.0 for Microsoft Windows (64-bit) (July 28, 2016)
Symbols that have been modified by loading the qm add-ons:

s	†	AngleBracket	MakeBoxes
OverHat	SubscriptBox	SuperDagger	SuperscriptBox
SuperStar			

Out[1]=

New keyboard aliases for this Mathematica session	
ESC qmket ESC	|■⟩ ket template
ESC qmbra ESC	⟨■| bra template
ESC qmbraket ESC	⟨■|□⟩ braket template
ESC qmsum ESC	$\sum_{\square=\square}^{\square}$ ■ sum template
ESC qmint ESC	$\int_{\square}^{\square}$ ■ d□ definite integral template
ESC qmprd ESC	$\prod_{\square=\square}^{\square}$ ■ product template
ESC qmpowe ESC	$■^{\square}$ power template
ESC qmconj ESC	$■^{*}$ complex conjugate template
ESC qmsubs ESC	$■_{\square}$ subscript template
ESC qmoper ESC	$\hat{■}$ operator template
ESC qmopes ESC	$\hat{■}_{\square}$ subscripted operator template
ESC qmopep ESC	$\hat{■}^{\square}$ power of operator template
ESC qmopeh ESC	$\hat{■}^{\dagger}$ hermitian of operator template
ESC qmopps ESC	$\hat{■}_{\square}^{\square}$ power of subscripted operator
ESC qmopsp ESC	$\hat{■}_{\square}^{\square}$ power of subscripted operator
ESC qmophs ESC	$\hat{■}_{\square}^{\dagger}$ hermitian of subscripted operator
ESC qmopsh ESC	$\hat{■}_{\square}^{\dagger}$ hermitian of subscripted operator
ESC qmcomm ESC	$[■, \square]_{-}$ commutator template
ESC qmanti ESC	$[■, \square]_{+}$ anticommutator template
ESC qmqmut ESC	$[■, \square]_{\square}$ q-mutator template
ESC qmexpe ESC	⟨■⟩ expectation template
These aliases begin and end with the [ESC] key	

Commutators

In[2]:=
```
qm[
 qmExpandCommutators[⟦â³, b̂²⟧₋]
]
```

Out[2]=
$$qm\left[\hat{b}\left(\hat{a}\left(\hat{a}[\![\hat{a},\hat{b}]\!]_{-}+[\![\hat{a},\hat{b}]\!]_{-}\hat{a}\right)+[\![\hat{a},\hat{b}]\!]_{-}\hat{a}^2\right)+\left(\hat{a}\left(\hat{a}[\![\hat{a},\hat{b}]\!]_{-}+[\![\hat{a},\hat{b}]\!]_{-}\hat{a}\right)+[\![\hat{a},\hat{b}]\!]_{-}\hat{a}^2\right)\hat{b}\right]$$

In[5]:=
```
qm[
 qmEvaluateCommutators[
  b̂ (â (â ⟦â, b̂⟧₋ + ⟦â, b̂⟧₋ â) + ⟦â, b̂⟧₋ â²) + (â (â ⟦â, b̂⟧₋ + ⟦â, b̂⟧₋ â) + ⟦â, b̂⟧₋ â²) b̂]
]
```

Out[5]=
$$qm\left[\hat{b}\left(\hat{a}\left(\hat{a}\left(\hat{a}\hat{b}-\hat{b}\hat{a}\right)+\left(\hat{a}\hat{b}-\hat{b}\hat{a}\right)\hat{a}\right)+\left(\hat{a}\hat{b}-\hat{b}\hat{a}\right)\hat{a}^2\right)+\left(\hat{a}\left(\hat{a}\left(\hat{a}\hat{b}-\hat{b}\hat{a}\right)+\left(\hat{a}\hat{b}-\hat{b}\hat{a}\right)\hat{a}\right)+\left(\hat{a}\hat{b}-\hat{b}\hat{a}\right)\hat{a}^2\right)\hat{b}\right]$$

In[6]:=
```
qm[
 qmExpandProducts[b̂ (â (â (â b̂ - b̂ â) + (â b̂ - b̂ â) â) + (â b̂ - b̂ â) â²) +
    (â (â (â b̂ - b̂ â) + (â b̂ - b̂ â) â) + (â b̂ - b̂ â) â²) b̂]
]
```

Out[6]=
$$qm\left[\hat{a}^3\hat{b}^2-\hat{b}^2\hat{a}^3\right]$$

In[7]:=
```
qm[
 qmReverseProducts[â³ b̂² - b̂² â³, 1]
]
```

Out[7]=
$$qm\left[-[\![\hat{b}^2,\hat{a}^3]\!]_{-}\right]$$

In[8]:=
```
qm[
 -⟦b̂², â³⟧₋
]
```
Out[8]=
```
qm[⟦â³, b̂²⟧₋]
```

Operator Algebra

In[9]:=
```
qm[
 qmExpandProducts[(b̂† + b̂)³]
]
```
Out[9]=
```
qm[(b̂†)³ + b̂† b̂² + b̂ (b̂†)² + (b̂†)² b̂ + b̂² b̂† + b̂† b̂ b̂† + b̂ b̂† b̂ + b̂³]
```

In[10]:=
```
qm[
 qmArrangeProducts[(b̂†)³ + b̂† b̂² + b̂ (b̂†)² + (b̂†)² b̂ + b̂² b̂† + b̂† b̂ b̂† + b̂ b̂† b̂ + b̂³, 1]
]
```
Out[10]=
```
qm[⟦⟦b̂†, b̂⟧₋, b̂†⟧₋ - ⟦b̂†, b̂²⟧₋ - ⟦(b̂†)², b̂⟧₋ - ⟦b̂†, b̂⟧₋ b̂† - ⟦b̂†, b̂⟧₋ b̂ +
  (b̂†)³ + 3 b̂† b̂² + 3 (b̂†)² b̂ + b̂³]
```

In[11]:=
```
qm[
 qmExpandCommutators[⟦⟦b̂†, b̂⟧₋, b̂†⟧₋ - ⟦b̂†, b̂²⟧₋ - ⟦(b̂†)², b̂⟧₋ - ⟦b̂†, b̂⟧₋ b̂† - ⟦b̂†, b̂⟧₋ b̂ +
   (b̂†)³ + 3 b̂† b̂² + 3 (b̂†)² b̂ + b̂³]
]
```
Out[11]=
```
qm[-(b̂† ⟦b̂†, b̂⟧₋ + ⟦b̂†, b̂⟧₋ b̂†) - (b̂ ⟦b̂†, b̂⟧₋ + ⟦b̂†, b̂⟧₋ b̂) -
  b̂† ⟦b̂†, b̂⟧₋ - ⟦b̂†, b̂⟧₋ b̂ + (b̂†)³ + 3 b̂† b̂² + 3 (b̂†)² b̂ + b̂³]
```

In[12]:=

```
qm[
 qmEvaluateCommutators[-(b̂† ⟦b̂†, b̂⟧₋ + ⟦b̂†, b̂⟧₋ b̂†) -
   (b̂ ⟦b̂†, b̂⟧₋ + ⟦b̂†, b̂⟧₋ b̂) - b̂† ⟦b̂†, b̂⟧₋ - ⟦b̂†, b̂⟧₋ b̂ + (b̂†)^3 + 3 b̂† b̂^2 + 3 (b̂†)^2 b̂ + b̂^3]
]
```

Out[12]=

$$qm\left[(\hat{b}^\dagger)^3 - \left(\hat{b}^\dagger\left(\hat{b}^\dagger\hat{b} - \hat{b}\hat{b}^\dagger\right) + \left(\hat{b}^\dagger\hat{b} - \hat{b}\hat{b}^\dagger\right)\hat{b}^\dagger\right) - \left(\hat{b}\left(\hat{b}^\dagger\hat{b} - \hat{b}\hat{b}^\dagger\right) + \left(\hat{b}^\dagger\hat{b} - \hat{b}\hat{b}^\dagger\right)\hat{b}\right) - \hat{b}^\dagger\left(\hat{b}^\dagger\hat{b} - \hat{b}\hat{b}^\dagger\right) - \left(\hat{b}^\dagger\hat{b} - \hat{b}\hat{b}^\dagger\right)\hat{b} + 3\hat{b}^\dagger\hat{b}^2 + 3(\hat{b}^\dagger)^2\hat{b} + \hat{b}^3\right]$$

In[13]:=

```
qm[
 qmExpandProducts[(b̂†)^3 - (b̂† (b̂† b̂ - b̂ b̂†) + (b̂† b̂ - b̂ b̂†) b̂†) -
   (b̂ (b̂† b̂ - b̂ b̂†) + (b̂† b̂ - b̂ b̂†) b̂) - b̂† (b̂† b̂ - b̂ b̂†) - (b̂† b̂ - b̂ b̂†) b̂ + 3 b̂† b̂^2 + 3 (b̂†)^2 b̂ + b̂^3]
]
```

Out[13]=

$$qm\left[(\hat{b}^\dagger)^3 + \hat{b}^\dagger\hat{b}^2 + \hat{b}(\hat{b}^\dagger)^2 + (\hat{b}^\dagger)^2\hat{b} + \hat{b}^2\hat{b}^\dagger + \hat{b}^\dagger\hat{b}\hat{b}^\dagger + \hat{b}\hat{b}^\dagger\hat{b} + \hat{b}^3\right]$$

In[14]:=

```
qm[
 qmCollectFromRight[(b̂†)^3 + b̂† b̂^2 + b̂ (b̂†)^2 + (b̂†)^2 b̂ + b̂^2 b̂† + b̂† b̂ b̂† + b̂ b̂† b̂ + b̂^3]
]
```

Out[14]=

$$qm\left[\left(\left(\hat{b}^\dagger + \hat{b}\right)\hat{b}^\dagger + \left(\hat{b}^\dagger + \hat{b}\right)\hat{b}\right)\hat{b}^\dagger + \left(\left(\hat{b}^\dagger + \hat{b}\right)\hat{b}^\dagger + \left(\hat{b}^\dagger + \hat{b}\right)\hat{b}\right)\hat{b}\right]$$

In[15]:=

```
qm[
 qmCollectFromLeft[((b̂† + b̂) b̂† + (b̂† + b̂) b̂) b̂† + ((b̂† + b̂) b̂† + (b̂† + b̂) b̂) b̂]
]
```

Out[15]=

$$qm\left[\left(\hat{b}^\dagger + \hat{b}\right)^3\right]$$

More operator algebra

In[16]:=
```
qm[
 qmArrangeProducts[â† â â† â]
]
```

Out[16]= $\mathrm{qm}\left[[\![[\![\hat{a}^{\dagger},\hat{a}]\!]_{-},\hat{a}^{\dagger}]\!]_{-}\hat{a}-[\![\hat{a}^{\dagger},\hat{a}]\!]_{-}\hat{a}^{\dagger}\hat{a}+(\hat{a}^{\dagger})^{2}\hat{a}^{2}\right]$

In[17]:=
```
qm[
 〚â†, â〛₋ = -1;
 qmArrangeProducts[â† â â† â]
]
```

Out[17]= $\mathrm{qm}\left[\hat{a}^{\dagger}\hat{a}+(\hat{a}^{\dagger})^{2}\hat{a}^{2}\right]$

In[18]:=
```
qm[
 Unset[〚â†, â〛₋];
 qmArrangeProducts[â† â â† â]
]
```

Out[18]= $\mathrm{qm}\left[[\![[\![\hat{a}^{\dagger},\hat{a}]\!]_{-},\hat{a}^{\dagger}]\!]_{-}\hat{a}-[\![\hat{a}^{\dagger},\hat{a}]\!]_{-}\hat{a}^{\dagger}\hat{a}+(\hat{a}^{\dagger})^{2}\hat{a}^{2}\right]$

In[19]:=
```
qm[
 qmExpandCommutators[〚â + b̂ + ĉ, d̂ ê f̂〛₋]
]
```

Out[19]= $\mathrm{qm}\left[\hat{d}\left(-\hat{e}\left(-[\![\hat{a},\hat{f}]\!]_{-}-[\![\hat{b},\hat{f}]\!]_{-}-[\![\hat{c},\hat{f}]\!]_{-}\right)-\left(-[\![\hat{a},\hat{e}]\!]_{-}-[\![\hat{b},\hat{e}]\!]_{-}-[\![\hat{c},\hat{e}]\!]_{-}\right)\hat{f}\right)-\left(-[\![\hat{a},\hat{d}]\!]_{-}-[\![\hat{b},\hat{d}]\!]_{-}-[\![\hat{c},\hat{d}]\!]_{-}\right)\hat{e}\hat{f}\right]$

In[20]:=
```
qm[
 qmExpandProducts[d̂ (-ê (-〚â, f̂〛₋ - 〚b̂, f̂〛₋ - 〚ĉ, f̂〛₋) - (-〚â, ê〛₋ - 〚b̂, ê〛₋ - 〚ĉ, ê〛₋) f̂) -
   (-〚â, d̂〛₋ - 〚b̂, d̂〛₋ - 〚ĉ, d̂〛₋) ê f̂]
]
```

Out[20]= $\mathrm{qm}\left[\hat{d}\hat{e}[\![\hat{a},\hat{f}]\!]_{-}+\hat{d}\hat{e}[\![\hat{b},\hat{f}]\!]_{-}+\hat{d}\hat{e}[\![\hat{c},\hat{f}]\!]_{-}+\hat{d}[\![\hat{a},\hat{e}]\!]_{-}\hat{f}+\hat{d}[\![\hat{b},\hat{e}]\!]_{-}\hat{f}+\hat{d}[\![\hat{c},\hat{e}]\!]_{-}\hat{f}+[\![\hat{a},\hat{d}]\!]_{-}\hat{e}\hat{f}+[\![\hat{b},\hat{d}]\!]_{-}\hat{e}\hat{f}+[\![\hat{c},\hat{d}]\!]_{-}\hat{e}\hat{f}\right]$

In[21]:=

```
qm[
 qmUnfoldPowers[(b̂^2 â^3)^5]
]
```

Out[21]=

$qm[\hat{b}^2\,\hat{a}^3\,\hat{b}^2\,\hat{a}^3\,\hat{b}^2\,\hat{a}^3\,\hat{b}^2\,\hat{a}^3\,\hat{b}^2\,\hat{a}^3]$

In[22]:=

```
qm[
 qmArrangePowers[b̂^2 â^3 b̂^2 â^3 b̂^2 â^3 b̂^2 â^3 b̂^2 â^3]
]
```

Out[22]=

$qm[(\hat{b}^2\,\hat{a}^3)^5]$