In[1]:= `Needs["SpinDynamica`"]`

```
SpinDynamica version 3.0.1 loaded
```

ModifyBuiltIn: The following built-in routines have been modified in SpinDynamica:

{Chop, Dot, Duration, Exp, Expand, ExpandAll, NumericQ, Plus, Power, Simplify, Times, WignerD}.

Evaluate ??*symbol* to generate the additional definitions for *symbol*.

opR (rotation operators)

In[2]:= `? opR`

opR[spins,angle] is the operator for rotating a single spin or a set of spins through the specified angle. If spins is absent, all spins in the current SpinSystem are rotated. The following formats for angle may be used: 1. {β,ϕ} indicates a rotation through β about an axis in the xy plane with the phase ϕ. The phase value may either be numeric, or be specified using the text codes "x", "y", "-x" for the quadrature phases. A code "z" indicates a rotation about the z-axis. 2. The format {ξ,{θ,ϕ}} indicates a rotation through the angle ξ about an axis with polar angles θ and ϕ. 3. The format {α,β,γ} indicates a rotation through the specified Euler angles, using the zyz convention.

1 spins-1/2

In[3]:= `SetSpinSystem[1]`

SetSpinSystem: the spin system has been set to $\{\{1, \frac{1}{2}\}\}$

SetBasis: the state basis has been set to ZeemanBasis$[\{\{1, \frac{1}{2}\}\}$, BasisLabels → Automatic$]$.

In[4]:= `opR[{β, "x"}]`

Out[4]= $R_{1\,x}(\beta)$

In[5]:= `MatrixRepresentation[opR[{β, "x"}]] // MatrixForm`

Out[5]//MatrixForm=

$$\begin{pmatrix} \text{Cos}\left[\frac{\beta}{2}\right] & -i\,\text{Sin}\left[\frac{\beta}{2}\right] \\ -i\,\text{Sin}\left[\frac{\beta}{2}\right] & \text{Cos}\left[\frac{\beta}{2}\right] \end{pmatrix}$$

In[6]:= `MatrixRepresentation[opR[{β, ϕ}]] // MatrixForm`

Out[6]//MatrixForm=

$$\begin{pmatrix} \text{Cos}\left[\frac{\beta}{2}\right] & -i\,e^{-i\phi}\,\text{Sin}\left[\frac{\beta}{2}\right] \\ -i\,e^{i\phi}\,\text{Sin}\left[\frac{\beta}{2}\right] & \text{Cos}\left[\frac{\beta}{2}\right] \end{pmatrix}$$

In[7]:= `MatrixRepresentation[opR[{α, β, γ}]] // MatrixForm`

Out[7]//MatrixForm=

$$\begin{pmatrix} e^{-\frac{i\alpha}{2}-\frac{i\gamma}{2}}\,\text{Cos}\left[\frac{\beta}{2}\right] & -e^{-\frac{i\alpha}{2}+\frac{i\gamma}{2}}\,\text{Sin}\left[\frac{\beta}{2}\right] \\ e^{\frac{i\alpha}{2}-\frac{i\gamma}{2}}\,\text{Sin}\left[\frac{\beta}{2}\right] & e^{\frac{i\alpha}{2}+\frac{i\gamma}{2}}\,\text{Cos}\left[\frac{\beta}{2}\right] \end{pmatrix}$$

In[8]:= `MatrixRepresentation[opR[{ξ, {θ, ϕ}}]] // MatrixForm`

Out[8]//MatrixForm=

$$\begin{pmatrix} e^{\frac{i\phi}{2}}\left(e^{-\frac{i\xi}{2}-\frac{i\phi}{2}}\,\text{Cos}\left[\frac{\theta}{2}\right]^2+e^{\frac{i\xi}{2}-\frac{i\phi}{2}}\,\text{Sin}\left[\frac{\theta}{2}\right]^2\right) & e^{-\frac{i\phi}{2}}\left(e^{-\frac{i\xi}{2}-\frac{i\phi}{2}}\,\text{Cos}\left[\frac{\theta}{2}\right]\,\text{Sin}\left[\frac{\theta}{2}\right]-e^{\frac{i\xi}{2}-\frac{i\phi}{2}}\,\text{Cos}\left[\right. \\ e^{\frac{i\phi}{2}}\left(e^{-\frac{i\xi}{2}+\frac{i\phi}{2}}\,\text{Cos}\left[\frac{\theta}{2}\right]\,\text{Sin}\left[\frac{\theta}{2}\right]-e^{\frac{i\xi}{2}+\frac{i\phi}{2}}\,\text{Cos}\left[\frac{\theta}{2}\right]\,\text{Sin}\left[\frac{\theta}{2}\right]\right) & e^{-\frac{i\phi}{2}}\left(e^{\frac{i\xi}{2}+\frac{i\phi}{2}}\,\text{Cos}\left[\frac{\theta}{2}\right]^2+e^{-\frac{i\xi}{2}+\frac{i\phi}{2}}\,\text{Sin}\left[\right. \end{pmatrix}$$

2 spins-1/2

In[9]:= `SetSpinSystem[2]`

SetSpinSystem: the spin system has been set to $\{\{1, \frac{1}{2}\}, \{2, \frac{1}{2}\}\}$

SetBasis: the state basis has been set to ZeemanBasis$[\{\{1, \frac{1}{2}\}, \{2, \frac{1}{2}\}\}$, BasisLabels → Automatic$]$.

In[10]:= `MatrixRepresentation[opR[{β, "x"}]] // MatrixForm`

Out[10]//MatrixForm=

$$\begin{pmatrix} \cos[\frac{\beta}{2}]^2 & -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] & -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] & -\sin[\frac{\beta}{2}]^2 \\ -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] & \cos[\frac{\beta}{2}]^2 & -\sin[\frac{\beta}{2}]^2 & -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] \\ -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] & -\sin[\frac{\beta}{2}]^2 & \cos[\frac{\beta}{2}]^2 & -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] \\ -\sin[\frac{\beta}{2}]^2 & -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] & -i\cos[\frac{\beta}{2}]\sin[\frac{\beta}{2}] & \cos[\frac{\beta}{2}]^2 \end{pmatrix}$$

In[11]:= `MatrixRepresentation[opR[1, {β, "x"}]] // MatrixForm`

Out[11]//MatrixForm=

$$\begin{pmatrix} \cos[\frac{\beta}{2}] & -i\sin[\frac{\beta}{2}] & 0 & 0 \\ -i\sin[\frac{\beta}{2}] & \cos[\frac{\beta}{2}] & 0 & 0 \\ 0 & 0 & \cos[\frac{\beta}{2}] & -i\sin[\frac{\beta}{2}] \\ 0 & 0 & -i\sin[\frac{\beta}{2}] & \cos[\frac{\beta}{2}] \end{pmatrix}$$

In[12]:= `MatrixRepresentation[opR[2, {β, "x"}]] // MatrixForm`

Out[12]//MatrixForm=

$$\begin{pmatrix} \cos[\frac{\beta}{2}] & 0 & -i\sin[\frac{\beta}{2}] & 0 \\ 0 & \cos[\frac{\beta}{2}] & 0 & -i\sin[\frac{\beta}{2}] \\ -i\sin[\frac{\beta}{2}] & 0 & \cos[\frac{\beta}{2}] & 0 \\ 0 & -i\sin[\frac{\beta}{2}] & 0 & \cos[\frac{\beta}{2}] \end{pmatrix}$$

3 spins-1/2

In[13]:= `SetSpinSystem[3]`

SetSpinSystem: the spin system has been set to $\{\{1, \frac{1}{2}\}, \{2, \frac{1}{2}\}, \{3, \frac{1}{2}\}\}$

SetBasis: the state basis has been set to ZeemanBasis$[\{\{1, \frac{1}{2}\}, \{2, \frac{1}{2}\}, \{3, \frac{1}{2}\}\}$, BasisLabels → Automatic$]$.

In[14]:= `Ispins = {1, 2}; Sspins = {3};`

In[15]:= `MatrixRepresentation[opR[{π/2, "x"}]] // MatrixForm`

Out[15]//MatrixForm=

$$\begin{pmatrix}
\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} \\
-\frac{i}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} \\
-\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} \\
-\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} \\
-\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} \\
-\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} \\
-\frac{1}{2\sqrt{2}} & \frac{i}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & \frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} \\
\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{1}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & -\frac{i}{2\sqrt{2}} & \frac{1}{2\sqrt{2}}
\end{pmatrix}$$

In[16]:= `MatrixRepresentation[opR[Ispins, {π/2, "x"}]] // MatrixForm`

Out[16]//MatrixForm=

$$\begin{pmatrix}
\frac{1}{2} & -\frac{i}{2} & -\frac{i}{2} & -\frac{1}{2} & 0 & 0 & 0 & 0 \\
-\frac{i}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{i}{2} & 0 & 0 & 0 & 0 \\
-\frac{i}{2} & -\frac{1}{2} & \frac{1}{2} & -\frac{i}{2} & 0 & 0 & 0 & 0 \\
-\frac{1}{2} & -\frac{i}{2} & -\frac{i}{2} & \frac{1}{2} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \frac{1}{2} & -\frac{i}{2} & -\frac{i}{2} & -\frac{1}{2} \\
0 & 0 & 0 & 0 & -\frac{i}{2} & \frac{1}{2} & -\frac{1}{2} & -\frac{i}{2} \\
0 & 0 & 0 & 0 & -\frac{i}{2} & -\frac{1}{2} & \frac{1}{2} & -\frac{i}{2} \\
0 & 0 & 0 & 0 & -\frac{1}{2} & -\frac{i}{2} & -\frac{i}{2} & \frac{1}{2}
\end{pmatrix}$$

In[17]:= `MatrixRepresentation[opR[Sspins, {π/2, "x"}]] // MatrixForm`

Out[17]//MatrixForm=

$$\begin{pmatrix}
\frac{1}{\sqrt{2}} & 0 & 0 & 0 & -\frac{i}{\sqrt{2}} & 0 & 0 & 0 \\
0 & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & -\frac{i}{\sqrt{2}} & 0 & 0 \\
0 & 0 & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & -\frac{i}{\sqrt{2}} & 0 \\
0 & 0 & 0 & \frac{1}{\sqrt{2}} & 0 & 0 & 0 & -\frac{i}{\sqrt{2}} \\
-\frac{i}{\sqrt{2}} & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & 0 & 0 & 0 \\
0 & -\frac{i}{\sqrt{2}} & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & 0 & 0 \\
0 & 0 & -\frac{i}{\sqrt{2}} & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & 0 \\
0 & 0 & 0 & -\frac{i}{\sqrt{2}} & 0 & 0 & 0 & \frac{1}{\sqrt{2}}
\end{pmatrix}$$