Visualizing Qubits on the Bloch Sphere Surface

In Section 2.1.2 of the text we introduced the Bloch sphere representation of a qubit. In it, a qubit $|\psi\rangle$ is represented by a matrix that is parameterized by the quantities $0 \le \theta \le \pi$, $0 \le \phi \le 2\pi$, so that

```
|\psi\rangle = \begin{pmatrix} \cos[\theta/2] \\ e^{/\phi} \sin[\theta/2] \end{pmatrix}
```

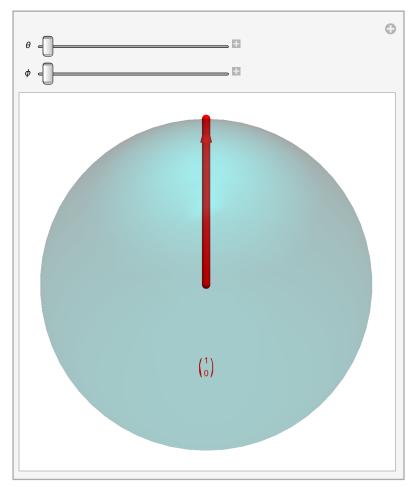
(up to an overall complex phase)

On the Bloch sphere surface, shown below, each point on the surface (except for the poles) is characterized by a unique value of $\theta\phi$. Therefore, we can represent the ket $|\psi\rangle$ by a vector (the red arrow shown in the figure below). In the visualization, you can adjust the levers to the desired values for θ, ϕ in order to graph the corresponding ket. In the figure the numerical value (up to an overall complex phase) is shown.

```
ClearAll["Global`*"]
```

```
\begin{aligned} & \operatorname{ket}[\theta_{-}, \phi_{-}] := \operatorname{Format}\left[ \begin{pmatrix} \operatorname{Chop}[\operatorname{Cos}[\theta/2]] \\ \operatorname{Exp}[\operatorname{I}\phi] \operatorname{Sin}[\theta/2] \end{pmatrix}, \operatorname{TraditionalForm} \right] \\ & \operatorname{vector}[\theta_{-}, \phi_{-}] := \\ & \operatorname{Arrow}[\operatorname{Tube}[\{\{0, 0, 0\}, \{\operatorname{Cos}[\phi] \operatorname{Sin}[\theta], \operatorname{Sin}[\theta] \operatorname{Sin}[\phi], \operatorname{Cos}[\theta]\}\}, 0.025]] \end{aligned}
```

```
bloch[θ_, φ_] := Show[Graphics3D[{Specularity[White, 100],
Lighting → {{"Point", Cyan, {1, 0, 1}}}, Opacity[0.2], Sphere[{0, 0, 0}]}],
Graphics3D[{Red, vector[θ, φ], Inset[ket[θ, φ], {0, 0, -0.5}]}],
Boxed -> False, ViewPoint → {Infinity, 0, 0}]
```



 $\texttt{Manipulate[bloch[θ, ϕ], \{θ, 0, Pi\}, \{ϕ, 0, 2 Pi}\}, \texttt{SaveDefinitions} \rightarrow \texttt{True}]}$