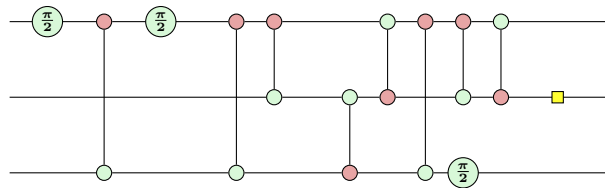


Introduction to Quantum Programming and Semantics 2026

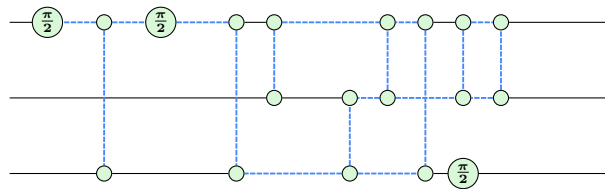
Tutorial week 9

Exercise 1

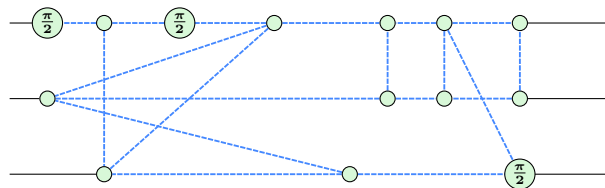
Start with the circuit:



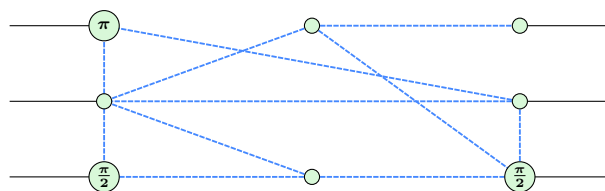
Change all the red dots to green dots:



Fuse all the spiders:



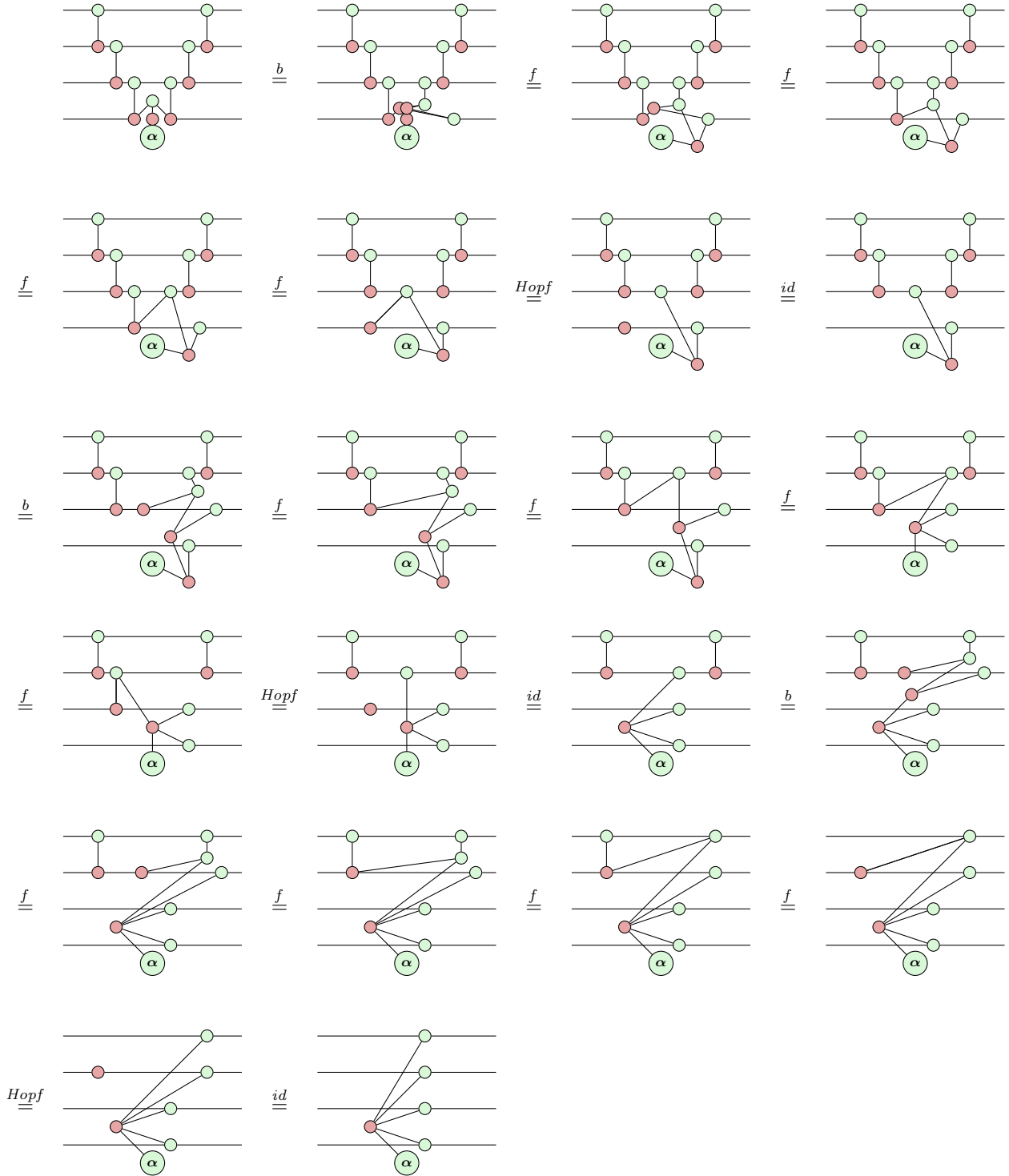
And do a local complementation on the internal $\frac{\pi}{2}$ dot:



Many other answers are possible, this is just one.

Exercise 2

We'll do it using elementary steps here:



It's less repetitive to use the equations from [KW] as lemmas.

Exercise 3

In general,

$$CCZ|abc\rangle = \sqrt{2} \left(\sum_{x,y,z=0}^1 (-1)^{xyz} \langle xyz|abc\rangle \right) |abc\rangle$$

The only term that survives is where $x = a$, $y = b$, and $z = c$. But $(-1)^{xyz} = 1$ unless $x = y = z = 1$, in which case it is -1 .

Exercise 4

