Building a quantum system in Quantum Composer

Part III: Superposition

3 Eigenstates and superposition

3.1 Linearity

The Schrödinger equation is *linear*. This means that if we have functions f_1 and f_2, both satisfying the equation, then any linear combination $Af_1 + Bf_2$ also satisfies the equation.

This, it turns out, is pretty useful. Remember the special energy levels that you calculated in *Quantum Composer* in the previous exercise? These aren't any old energy levels, but *eigenstates*. *Any* solution to the Schrödinger equation can be expressed as a linear combination of eigenstates.

3.2 Investigating superposition

Open the file `Exercise2.flow` in *Quantum Composer*. Locate the box marked **Linear Combination**. The program has calculated the first five eigenstates of the simple harmonic oscillator. The box you've located allows you to add together the different solutions with different coefficients (A and B above). There are also two graphs: the **Energy Plot**, which you've seen already, and the **Position Plot** which plots $|\Psi(x)|^2$.

First, try typing `1` into one of the boxes in the left hand column, and `0` into the others (as shown in Figure 1). Press play. What happens? [*Hint: nothing exciting.*] Test all five combinations with just one `1` — these are the five lowest eigenstates — and don't forget to hit the red reset button between runs. What can you conclude about the time-dependence of eigenstates?

Now try typing `1` into the first two boxes, and `0` into the other three. Press play. What happens? [*Hint: a bit more exciting this time.*] Attempt the following tasks:

- Change the sign of one of the numbers in the linear combination box. How does the evolution change?
- Try to include more states in your linear combination. Can you get an oscillation centred on zero?
- Is it possible to create a superposition that does not evolve with time?
- If you change the frequency of the potential (in the box marked **Frequency**) what happens to the time dynamics of the system?

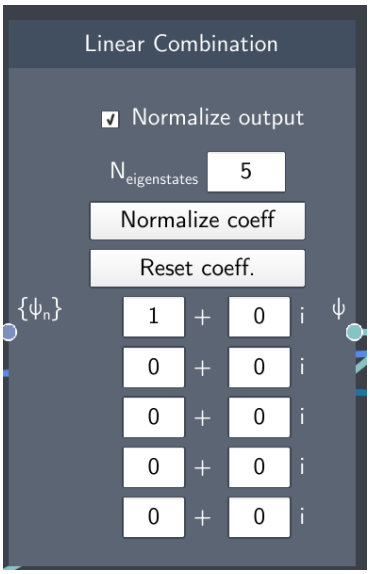

Figure 1: The **Linear Combination** box, where we are outputting just the first eigenstate.