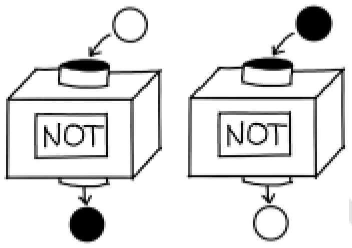
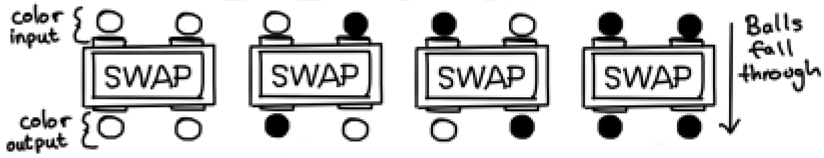
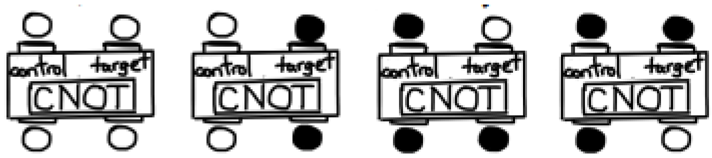
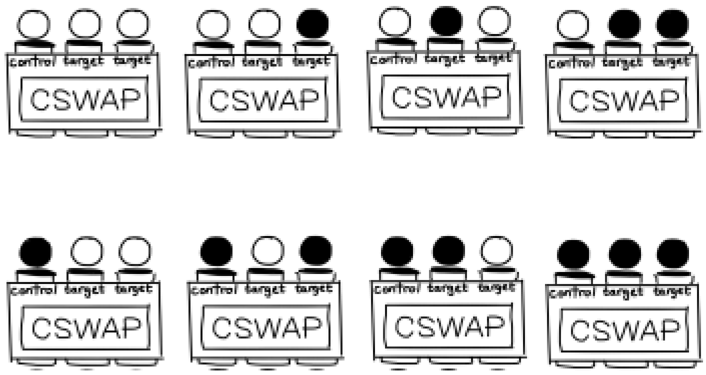
Traditional Computing



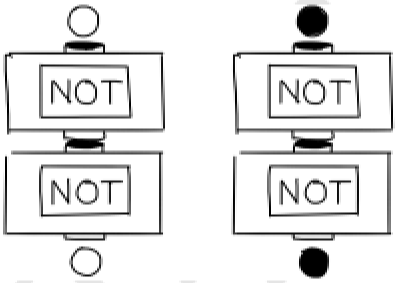




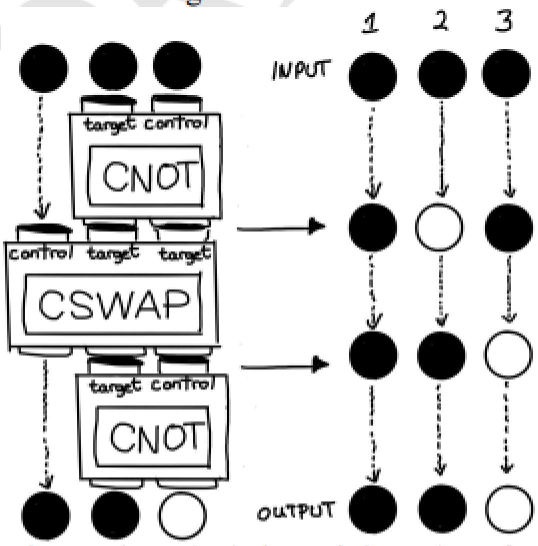
Can you complete the outcomes of these boxes?



The next thing to consider is that by stacking boxes on top of each other, we can use the output of one box as the input to another. For example, we can stack two NOT boxes, and the resulting transformation is that the color of the ball stays the same:

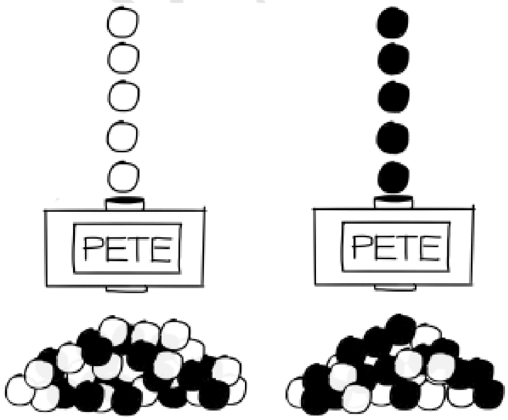


We can repeat this stacking trick to execute more sophisticated transformations of balls. For example, consider this arrangement:

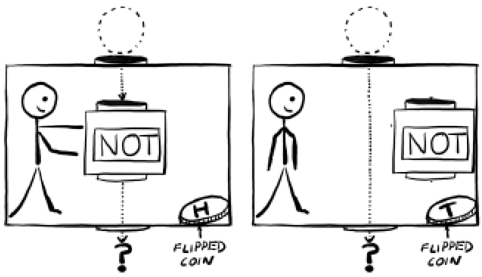


On the right, I have shown the calculation of the color of each ball progressing through the boxes, for the case when all three balls we drop in to the physical setup on the left are black. If we do a similar calculation for the other seven possible input configurations what do we get?

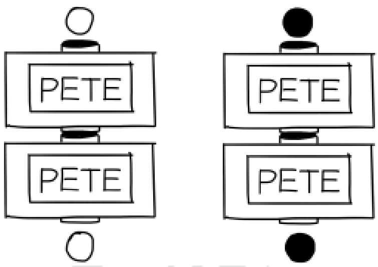
The PETE box has only a single hole in both the top and the bottom. After playing with it for a while, we find that regardless of the color of the ball that we drop in, when it emerges from the bottom it is equally likely black or white; and from one use of the box to the next there is no pattern, no rhyme or reason, about which color the ball emerges:



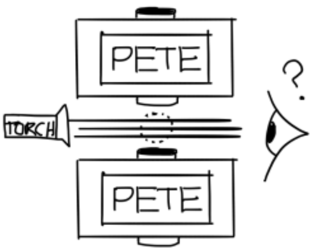
Is the behavior of the PETE box really so different from the boxes above? Of course the ones above behaved perfectly predictably, while the PETE box is unpredictable—which color emerges is completely random. So far we have deliberately not asked any questions about what goes on inside the boxes we have encountered. All we have considered is what they do that we can actually observe. As described thus far, however, the PETE box's possible inner workings are not necessarily particularly strange. We can imagine building a box with an internal mechanism which flips a coin. If the coin shows tails, it lets the ball travel through directly; but if it shows heads, a NOT box is inserted into its path:



If this was the explanation of the inner workings of the PETE box, it would not be a radical addition to our collection of boxes. However, when we stack two PETE boxes, something remarkable happens: if we drop a white ball in the top of the first PETE box it always emerges white from the bottom of the second box. Similarly, if we drop a black ball in the top box it always emerges black from the bottom of the second box:



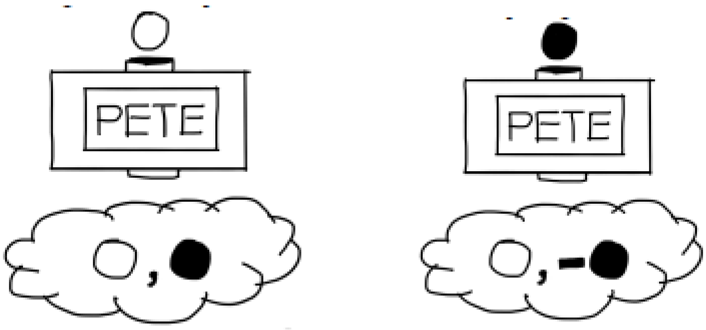
Can you see why this behavior is puzzling? It is critical that you do. The second PETE box, regardless of whether the ball entering it from the first box is black or white, should sometimes output a black ball and sometimes a white ball, because inputting a white ball leads to a random color emerging and inputting a black ball also leads to a random color emerging. But that is inconsistent with what is happening when we stack the boxes; stacking them leads to a completely predictable, non-random output.

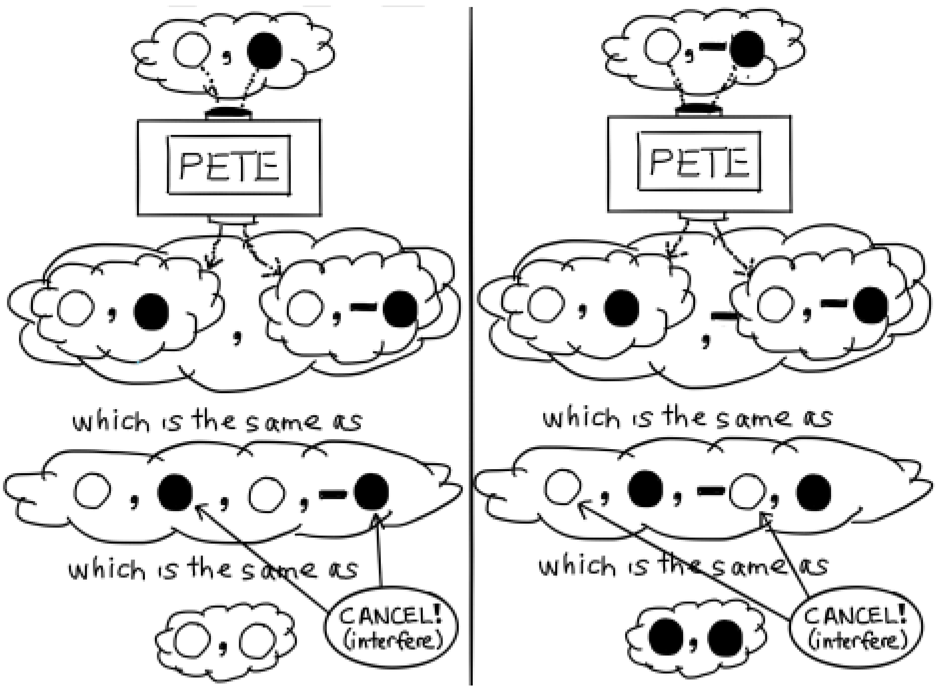


But it doesn't work if we look in the middle!!!!

Representing superpositions, the new state of physical/logical being

To represent a superposition of black and white—and capture this new type of ambiguity between the ball being black and the ball being white—we draw a cloud into which we list both possibilities, separated by a comma:





Qubits

As we explore in our open step on qubits, traditional computers are built on bits. These bits (short for binary digits) are the basic units of information in computing, where two distinct configurations can be measured. They can be thought of as on or off, up or down, or, as encoded in binary, as either 0s or 1s.

In quantum computing, quantum bits or qubits form the basics of how these computers work. These qubits can be made from quantum-mechanical systems that can have two states. For example, the spin of an electron can be measured as up or down, or a single photon is either vertically or horizontally polarised.

Superposition

Unlike traditional computing bits, which can be either 0s or 1s, qubits can exist as either 0s or 1s, or a mix of both simultaneously. This phenomenon, known as a state of superposition, means that all combinations of information can exist at once.

When qubits are combined together, this ability to hold all possible configurations of information at once means that complex problems can be represented far easier than with traditional computing methods.

You can learn more about the principles and properties of superposition on our open step on the subject.