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Welcome back to 8.701. So in the last two videos, we looked at the Dirac equation and we looked at solutions Dirac equations. And in the last lecture we found that, along with positive energy states, we had those negative energy states. Since we cannot simply drop them or disregard them, we do have to find physical interpretation for these negative energy solutions.

KLUTE:

The first one which was put forward, is the one where you think about negative energy states all being populated-- and that is the vacuum. The vacuum is basically a sea full of negative energy states which are all populated. So if you have a positive energy state, and there are electrons sitting in this energy state here, the electron, because of the Pauli exclusion principle cannot fall down into the negative energy state.

But you are able to kick them out, for example, to excite them with a photon. Very excited. The negative energy state, you get an electron out. This process is then will lend to the creation of a positron and an electron pair with a photon. [INAUDIBLE] pair production.

It can also explain undulation where there's an empty and a negative energy stage where the electron just folds into creating a photon. So while the interpretation is useful and it explains pair production and undulation processes, they fail to explain what this vacuum, the sea of negative energy state even is.

So a more useful interpretation is one part forward that Feynman and Stückelberg, which came out of the discussion of quantum field theory. And we already discussed this interpretation when we looked at Feynman [INAUDIBLE]. So have a look at this Feynman diagram here where you have an electron with a positive energy and an electron with a negative energy, building a photon, which is twice the energy in the symmetric configuration of the electrons before.

And you're interpreting the negative energy solution here of the electron as the electron moving backward in time. This is an equivalent to a positron with a positive energy and an electron with a positive energy where the positron and the electron move forward in time. Again, in both cases, you see the energy of the photon is two times the energy of those two particles.

All right. So this is a very short discussion. And we will see later on how we use the spinodes for antiparticles together with spinodes for particles order to make relations that could have matrix element. And so we move forward with our discussion of Feynman rules, this time now, with spin-1/2 particles included.