MARKUS KLUTE: All right. So welcome back to 8.701. So we have all ingredients now to prepare Feynman rules for QED. So that's the toolkit we need in order to make calculations to calculate scattering processes and decays.

And we've already seen Feynman rules for our toy theory. Again, now the situation is a little bit more complicated, because we can consider the spin of particles in addition to their energy and momentum. The rules' sequence of things are very much the same. There is, however, a few caveats to keep in mind, and I'll point those out.

OK. So the very first thing is to be very clear in our notation. So this is an arbitrary or generic QED Feynman diagram. We have only pointed out the incoming and the outgoing lines. There is internal lines which I didn't mention here. Important to note the momentum and the directions. The directions are arbitrary. We just have to be clear on them and then treat them consistently. All right? So this is not different in our previous discussion.

Then, here comes the difference. Our external lines either electron, positrons, or photons. All right? You can-- fermions and photons, charged fermions and photons. So we discussed how the solutions look like, our spinors u and v. And for outgoing electrons, for outgoing particles, we have this adjunct vector here, which is given by u dagger gamma 0. And similarly for the incoming antiparticle-- v dagger gamma 0. For the photon, we have the polarization vectors for incoming and outgoing photons.

All right. Then we have a vertex factor. Here, now, g e is a constant and a dimensionless property. But we do have to have a gamma mu here as part of our vertex factor.

For the propagator, our internal lines, we have a difference between electrons, positrons, and photons. And that comes from the fact that electrons and positrons are massive particles. So we have vertex vectors which now have this 1 over q square behavior, or 1 over q square minus m square behavior. So here, you can already see that there's going to be a complication later when we evaluate or integrate over momentum-- simply the same discussion I had before. And we already know how to solve this problem of infinities by renormalizing-- by having a cut-off and renormalizing it.

Excellent. So the next step, then, is very much the same. There's no change. We have to make sure that there's energy and momentum conservation, and we enforce this by introducing delta functions. We have to integrate over each and every internal momenta, and each internal line gets one of those integration factors. And then after we integrate, we are left with a delta function, and we have to cancel that delta function.

All right. In our toy experiment, the order of things didn't matter. Everything we had in there was scalar numbers, right? Here we do have a little bit more complicated problem. So there's an importance in the order of which we execute things. So what we want to do is form fermion lines. We just follow a fermion as we go from the left to the right. And then we find things which are always of the form an adjoint spinor, a 4-times-4 matrix, and a spinor. And the result of that is going to be a number. All right? Great.

There is one additional complication, is accounting for duplications and making sure that the sign is [INAUDIBLE]. I'm just mentioning this here. This will become more clear as you work through examples. So there is an antisymmetrization going on, where we have to introduce a minus sign between different diagrams that differ only by the interchange or the exchange of two incoming or two outgoing electrons or positrons and/or the incoming electron with an outgoing positron. So if you have a diagram which is exactly the same, but the two incoming electrons are interchanged, you have to add those two diagrams. You have to add all matrix elements together for recalculating amplitude. But you have to introduce a minus sign when you change those two particles.

So with that, we can now just basically calculate whatever QED process we want. All the tools are already here. And what we want to do now next, in the next video, and also in the recitation and homework, is to go through a few examples to get a little practice with this. There's a number of tricks which will come in handy, and I'll explain those in a separate video. They are just mathematical tricks which allow us to quickly evaluate the multiplication of spinors and matrix elements and so on.

All right. That's it for this video. Again, there is going to be another two or three videos which deal with actually evaluating or calculating matrix elements.