MARKUS KLUTE: Welcome back to 8.20 Special Relativity. In this section, we're going to talk about the emission and the absorption of photons. So you can think about a scenario where you have an atom which emits a photon, like in this picture here. And to create a new atom, which we call the atom prime, in the absorption process, you have a collision between a photon and the atom. And you make a new atom, again, indicated by a prime.

So I want you to actually work this out in two activities. The first one is on absorption. So here we have a stationary particle, the atom, with a mass M0, and it's struck by a photon. We have this scenario here.

And the photon has an energy, Q, and becomes-- and there's a new particle coming out with the rest mass M0 prime and recoiling velocity, it has to have some sort of momentum, v. And so the question is, how can we now find the mass of this new particle and the velocity? So please stop the video, and try to work this out.

So the way to work this out is by writing energy and momentum equation. You can do this just with a four-vector. even though we are not performing any Lorentz transformation in this part, you can just write on the four-vector. And this needs to be conserved energy. And momentum need to be conserved in this correlation.

All right, so we have the mass of this initial particle at rest. So the energy is M 0 C square. The energy of the photon is Q. The momentum of the photon is Q over c. And so then the final particle-- the outcoming new particle has its own mass, but it has a boost. So the total energy is M 0 prime gamma using the velocity of this particle, C square. And the momentum is M 0 prime gamma times v. So that's after the correlation.

And so then you can use the energy relation in order to get to the mass. This is a function of the velocity here. And you can get the velocity by looking at the momentum. So you basically solve for this v or v over c in this case. And then if you want, you can add this back in here in order to get the mass as a function of the mass of the initial particle and the energy of the photon.

The second example now is the emission. So here we have a stationary atom with a rest mass M0. And it emits the photon, this energy Q. And it becomes the new atom with rest mass M0 prime and recoiling with the velocity. Now given the two masses, what is the energy of the photon? Q.

So we set this up in the same way as before. Now we start with this particle at rest. And the energy is M 0 c squared. Momentum is 0. And that's equal to the energy and momentum of the new particle and the photon, in the very same way as we set this up before.

So now what you want to do here is use our invariants of the four-vector using the energy and momentum relation. So the mass of this new particle times c square squared is equal to the energy squared . The energy squared-- you just bring this over here-- is M0 c squared minus Q squared. And then the momentum is simply of this new particle, is simply Q square.

This you cannot solve for Q. And you find this relation here. So that's the energy of the outgoing photon.

If you now define Q0 as the difference in masses or the difference of the masses times c square, then you can write the energy of the photon as Q0 times 1 minus Q0 over 2M c square. And that's always smaller than the difference in masses.

So if you now analyze this and look at this some more and try to understand what it means, what we find is that the emission and the absorption, they only occur at a very precise value of the energy of the photon. It also means that an emitted photon can only be reabsorbed if the particles are moving with just the right velocity.

So if you're an atom, and the photon goes out, and your neighboring atom is just sitting there next to you at rest as you were at rest before, it is not able to reabsorb the photon. So we learned just by using special relativity quite a bit about the physics involved in absorption and emission of photons.