MARKUS KLUTE: Welcome back to 8.20, Special Relativity. In this section, we're going to further investigate the energy momentum for vector, which we introduced in the previous sections. But here, we focus on the zeroth component, the first component of this vector, where we find mass in A for particle A times the proper velocity of the zeroth component is equal to mA times c times 1 over 1 minus uA square over c square, which is the energy of this particle A over c. Or in other words, the energy is equal to the mass times c square over 1 square root of 1 minus uA square c square.

So let's discuss or look at-- let's have a look at this a little bit more. The first question we can ask-- how does this now look like for particles which travel with reasonably low velocity? So uA-- much smaller than c. So we can Taylor expand this following this equation here, which we discussed earlier.

And we find that the energy is equal to mA c square. That's the first term, which we call rest mass, the energy given-- just the rest mass by the mass of the particle times c square, plus 1/2 mA c square times uA square over c square. The c squares cancel.

And we find what we know as the kinetic energy, 1/2 m v square, or in this case, 1/2 mA uA square. That looks very familiar. So the energy of a particle is given by its rest mass plus its kinetic energy.

All right, now investigating this for vector, then we can ask, how does the invariant interval look like? How does this property, which is invariant, and the Lorentz transformation look like when we multiply the vector with itself? Here, we find minus E square over c square plus the 3 momentum squared is equal to minus m0 c square. Or in other words, we find this energy momentum, energy mass relation, energy momentum mass relation, where the energy is given by the momentum square times c square plus the rest mass square times c to the 4th power.

Again, we can unroll this now and ask, how does this look for a particle at rest? And again, we find the energy is equal to mc square. No surprise. That's how we started the definition of this. In general, we can find that the energy is equal to a relativistic mass times c square, which is equal to the rest mass times gamma times c square. And that's equal to the rest mass times c square plus k, the kinetic energy, square.

All right, does this definition-- I can tell you that this confused me as a student quite a bit. This understanding that the mass becomes heavier for a part of this-- really, one I didn't quite like. I just like to think about the fact that the kinetic energy-- there's a relativistic component to the kinetic energy, which is owned by the particle in addition to the rest mass of this particle times c square.

Also interesting to note is that for particles at rest-- particles which are massless, like a photon, the energy is equal to the momentum times c. If you want to know what the energy is of a photon, you need to know what the momentum is of the photon multiplied by c.