PROFESSOR: OK, so that's our equation. Three terms-- first term, spontaneous emission, second term, stimulated emission proportional to Nb, third term increases Nb's absorption. Our strategy now is, so what do you do with this? This looks like a good equation, but what are we to do?

We haven't used three, really. So we can solve for U. And this time, the equation won't want to make U equal 0.

It will give us something. And then we can compare with a thermal equilibrium relation to get something. So that's our goal.

So how do we solve for U? Let's divide by Nb. So divide by Nb. So a 0 here, pass this to that side, and divide by Nb.

So you get A on the left-hand side equals-- let's see, should I put the-- well, minus Bba Nb. Actually, I'll do it like this-- the second term first. Bab Na over Nb times U-- so I'll put it here, a U of omega Ba-- minus Bba.

OK, so I moved the first term to the left-hand side, grouped the U. Why did I group the U? Because I said, let's find what U is, and try to compare with other things that we have.

So now we can solve for the U. U of omega ba is equal to A divided by this quantity. So it's A divided by a big thing. Let me factor out the Bab.

So now we have here Na over Nb minus Bba over Bab, or A over Bab 1 over Na over Nb is there, is e to the beta h bar omega ba-- It's a minus sign with respect to number 2-- minus Bba over Bab. OK, this is great. We're in very good shape.

In fact, we're here. Let's compare with our thermal radiation. So here is what we got. And we have to compare with fact number three, which is the thermal radiation formula, which is h bar over pi squared C cubed omega cubed 1 over e to the beta h omega.

And I'm comparing with the thermal radiation, U of omega ab. I canceled the D omegas, because this is U without the D omegas. So omega ba minus 1. All right. It's perfectly nice and ready.

We need to compare this formula with this one. They have to be equal. Well, this factor, must

be equal to this factor, given that here you have e to the beta h bar omega ba. These are constants.

And the first thing that you discover is Bba equal Bab. And so yes, very nice. This is what we learn in perturbation theory.

These two processes have identical rates. So the first statement that this equality requires is that Bab is equal to Bba. So there's just one B coefficient, just like there's one A coefficient.

And the second thing that you learn is that A over Bab is this ratio-- is h bar omega ba cubed over pi squared C cubed. So we will be able to calculate the B coefficients, because they represent the familiar properties of harmonic perturbations transitions, and we've done already.

Calculating A is harder, in principle. The process of spontaneous emission is a harder process. But this relation says that we don't have to worry about it. We already, if we know B, these are constants, we know A.

So many times, even in problems in the homework, you will be asked, what is the spontaneous transition rate for this decay? You have an oscillator. It's in an excited state. What is the rate of spontaneous transition?

And then you say, OK, this is complicated. But you calculate the stimulated transition rate, and then plug in this coefficient. So it will not be difficult.

Now, spontaneous emission, as we discussed there in the top, doesn't include the factor having to do with the density of photons, the U that tells you how many photons there are. Because the photons play no deep role in producing the transition. But at some level, this transition-- while it's not stimulated by the photons that are flying around-- when you calculate it, in a serious, detailed calculation, you can think of them as stimulated by the vacuum fluctuations of the electromagnetic field.

So if you were to quantize the electromagnetic field, there are vacuum fluctuations. And those vacuum fluctuations, you could say, they are stimulating what we call "spontaneous emission." So at the end of the day, the electromagnetic field is a quantum field. And therefore, it has zero point energies, Casimir effects, vacuum fluctuations.

You can't get away from it. So in some sense, everything is stimulated emission, stimulated by

a lot of photons or stimulated by the vacuum fields. Anyway, we'll still remain with the name "spontaneous emission," and keep those things very distinct.

These rates have different effects at different temperatures, as well. So we'll consider that, for example, in that at low temperatures, the black body radiation has a very little number of photons. So most of the transitions, if they occur, are happening due to spontaneous transitions.

On the other hand, as you increase the temperature, the number of photons that are available per unit volume increases, and stimulated emission takes over. So these are the different contributions to the rates. And it gives you a perspective-- at very low temperature, spontaneous dominates. At very high temperatures, stimulated emission dominates.