PROFESSOR: All right, spin orbit.

We have it still there, delta H spin orbit, orbit.

Well, we know what V is. So that derivative, dv dr can be taken care of, the 1 over r. That gives you e squared over 2m c squared 1 over r cubed S, L. And you remember that S, L, from 805, J squared minus S squared minus L squared. The reason that's why you tend to do addition of angular momentum, because S and L, calculating the matrix elements of this thing is very easy, in that base is because every state there has a fixed value of S squared, a fixed value of L squared. And j squared plus a couple of possibilities.

So we must work with the couple basis. Basis. And therefore, we can attempt to find E1 of a N, L, J, MJ, spin orbit, equal e squared over 2m squared c squared and LJ, MJ, S, L, R cubed. The R cube has to stay inside the expectation value, because the expectation value includes integration over space. So this is a very important.

N, L, J, MJ. And again the useful question, the couple basis will have we have degeneracies. All the states are degenerate there. So this time, we fixed n, because the degeneracies happen only when you fix n. So do we have the right to do this, to use the formula form perturbation, the non-degenerate perturbation theory to do this calculation?

And the answer is yes, because the perturbation S.L over R cubed commutes with with L squared, with J squared, and with Jz. you need all that because you can have degeneracies by having different L values. And that would be taken care by this operator that has different eigenvalues when L is different.

You can have the degeneracies involving different J values. This would be taken by this operator. And you can have degeneracies when m has different value so that involves the Jz operator. So you really need a perturbation that commutes with all of them.

And why does it commute with all of them? You can see it in several ways. Let's do L squared. L squared is Casimir, it commutes with any LI. It doesn't even think about S because it doesn't know anything about S. So it commutes with S. So L squared with any LI and commutes with S. And L squared is an invariant, it commute with r squared because r squared is rotational invariant. So everything commute with that.

In order to do the other ones, you can also think in terms of this matrix J squared over here and S squared and do all of them. You should do it and convince yourself that they all commute. So we can do this. If we can do it, it's good because then we can evaluate these quantities.

So let's do a little of the of the evaluation. So this E1nljmj is equal to. Let's evaluate the S dot L part by using 1/2 j squared s squared minus L squared. So that gives you a factor of h bar squared over 2, with this 2 over there. So you get e squared h squared over 4m squared c squared, J times J plus 1 minus l times l plus 1 minus 3/4, times nljmj, 1 over r cubed, mljmj.

OK. That should be clear from the fact that you have a j squared minus s squared. That's a 3/4 spin is always 1/2, and l squared. This is known. It's equal, in fact, to nlml 1 over cubed nlml. Which is equal, let me discuss that again. It's a little-- a0l, l plus 1, l plus 1/2.

OK. So this is a known result. It's one of those expectation values that you can get from Feynman, Hellman, or for other recursion relations. And this is always computed in the original uncoupled basis. But we seem to need it in the coupled basis. So again, are we in trouble? No. This is actually the same.

And it is the same only because this answer doesn't depend on ml. Because this states involve various combinations of ml and ms. But doesn't depend on ml, so the answer is really the same. So these things are really the same.

Happily, that simplifies our work. And now we have E1 nljm is equal to En 0-- this is yet another notation, this is the ground state energy here-- mc squared n, j, j plus 1 minus l, l plus 1 minus 3/4, over l, l plus 1/2, l plus 1. OK this is spin orbit.