Good afternoon.
Today we are going to introduce MRI physics.
As I mentioned earlier, I am supposed to give a talk in Austria, talking about the readout transform of the arm machine learning.
I will record this lecture so you can see me as if I am here.
Anyway, this is online.
I am a physics.
So, first I will give you a preview and a preview.
Preview is a big picture about the arm machine.
I will give you a basic knowledge and a rather introductory staff.
You will need to understand later content better.
First, see this big picture.
So far, we learned x3ct and nuclear imaging.
It is a hybrid and a hybrid.
So, you just learned that.
And I explained x3 computer tomography and a hybrid and a hybrid.
I mentioned these two imaging modalities.
Highly complementary.
The CT gave you structural and atomic information.
The nuclear imaging and the subagut and the part gave you functional information by introducing radio tricero into human body, participating biochemical reaction.
A lot of information.
So now we move to the third imaging modality.
IMAI.
IMAI is very unique.
I can't give you both an atomic and functional information.
As we, let me just turn the cursor on.
I hope you can see this.
In the nuclear imaging part, I mentioned the nuclear imaging is important.
It will be more valuable if you put an atomic information and functional information in the comments for you more.
So we have part CT scanner.
It's a dual imaging modality scanner.
And very popular in radiation oncology setting.
So right now we have these two imaging modalities combined.
And also, Siemens, GE and other companies put part and IMAI together.
So CT IMAI hasn't been combined in market place yet.
And I mentioned to you that we are working on this combination.
So this is kind of major trend.
So nuclear, CT and IMAI, even truly, they will be unified.
And they have part CT, part IMAI.
And we, baby, if we sooner or later, will have a CT IMAI.
And you could have a scanner to do nuclear imaging CT and IMAI, Altagaser, that will be intersection here.
Okay, this is a big picture.
Now we are talking about IMAI, the first lecture today.
And let me give you IMAI milestones.
So not many, but nice to remember these key facts.
Very exciting.
IMAI, IMAI, is magnetic resonance specific to self-tatial types.
And so, self-tatial types.
And then we can have anatomical mapping, so anatomical information, kind of like CT.
And also IMAI can measure blood oxygenation level.
So that will give you functional information.
So you have bells.
And 1946, nuclear magnetic resonance, or IMAI, was invented.
And they will block and press out, and they will know their price.
And they will later slice of the visual mindset, they say again.
And the resonance imaging only got all of the signal from a whole sample.
And the magnetic resonance imaging is not just the overall measurement.
Really, you do tomography and mapping.
So you have many pixels and voxels.

The trick is to introduce a called gradient field.
And then we will come to that later on.
And they will private pretty much, went to Latin border, and they said professor.
And he and the others went, Nobel Prize in medicine, 2000 to three.
And then they found MRI other mouse, so you can read.
And they went, you have human IMAI images, and that will be, that was in later seven days.
And the commercial IMAI scanner, and the unit only eight days.
And the functional IMAI human, so you can look into functional information, particularly brain function.
And now they are talking about brain initiative.
IMAI plays a key role to unlock mystery, and what you think, and again, we will explain more later.
So these mouse bones are next to no, okay, general knowledge.
And the EU book chapter, I hope you already read a good portion of the IMAI chapter.
The text book.
And I think from 170 pages, just keep reading, and now you read about 10 to 20 pages, general knowledge.
And the first figure you see, and they're talking about how you can make IMAI images, and the very general idea, they're working principle, so you have a big superconducting, superconducting magnet.
And then you have a grid in coil to introduce the field, so that you can do the demographic imaging.
And the other way, you need the RRF coils.
You send RRF waves to outside, so called magnetic-sacen vector.
So you turn the N-vector into certain angle and you induce radio frequency signals, and you do some flow analysis, reconstruct the images.
Certainly you wouldn't understand all of these details at this moment, and then we will get into deeper and deeper level.
So these basic ideas are very cool, and the text book described is okay, but just too brief.
I think it would be nice to see how art works, how to export, how to play IMAI imaging principle.
And we want to have a rough idea, a big picture, and you just see how this lecture, this instructor, how to play the key ideas in a few minutes, and the pay attention, so let me play.
Just the...
Magnetic resonance imaging, or IMAI for short, can be modeled in the following way.
Let's first consider this conducting loop of wire.
The magnetic dipole moment is defined as the current going into the magnetic-sacen vector.
Magnetic resonance imaging, or IMAI for short, can be modeled in the following way.
Let's first consider this conducting loop of wire.
The magnetic-dipole moment is defined as the current going through the wire, times the cross-sectional area that that wire encloses, times a unit vector that is perpendicular to the surface area.
So that the magnetic-dipole moment points in the direction that is perpendicular to the surface area, like so.
So we define this.
And a proton is believed to spin on its axis at the subatomic level.
And so because it's spinning, the magnetic-dipole moment is the sum of the bunch of little current currents.
Okay, so whenever you take a dipole moment, and you put it in the external magnetic field, you can see that the magnetic-dipole moment is a constant.
So, if you take a dipole moment, you can see that the magnetic-dipole moment is a constant.
So, when you take a dipole moment, and you put it in the external magnetic field, it will expand as a torque.
And that torque is given by the following equation.
New cross-b.

And what this says is that basically, this dipole moment here, the magnetic-dipole moment, will tend to line up with the magnetic field.
So look, here's the b-field, here's the magnetic-dipole moment, we cross this and it into here, and we get a torque out of the board, which means this thing is going to rotate this way.
It rotates in the direction of the fingers, and so this thing will be torqued this way, right? So, the magnetic-dipole moment will have a tendency to line up with an external b-field, but it won't line up all the way.
It will line up the angular momentum of the spinning top, so to speak, will prevent it from lining up completely, but then it will have a procession axis like so.
So you can consider this thing like a top, it's rotating on its axis, but then also processing about a procession axis, where the procession axis is in the direction of the external magnetic field, okay? Much like a top.
Now, we're going to take some radiation and emit that radiation laterally towards the procession axis.
I have not drawn, this is an electromagnetic wave, but I have not drawn the electric field component just for the sake of a clean picture that's useful for description.
And so we see this thing is oscillating in and out of the board, like so, and traversing laterally towards the procession axis.
And if the angular frequency of this is equal to the angular frequency of this, we will have resonance.
So we can define a mega L, the little more angular frequency, to be equal to gamma times the external b-field that's applied, b0.
And so this value here is 2.67 times 10 at the eighth, okay? And then, so if we substitute 2 pi f, this converts radians per second to oscillations per second.
So we have 2 pi f, and this is f sub l, is equal to gamma b0.
And then, if I'm going by 2 pi, we get f sub l, is equal to gamma over 2 pi on b0.
And then this is equal to 42 megahertz, that is times 10 to the sixth, per unit tesla, like this times the external b-field as applied.
Okay? So the frequency of this thing is matching the frequency of this guy, and whenever he comes around, saying when he's like, right here, this guy is coming in, and so he's coming into contact with this b-field vector that is out of the board.
And so as a result of the cross-product, they want to line up with one another, he expands as a torque that tends to line him up, and so he flattens out this way.
But then as he continues to process around, this guy, see this guy back here is coming, and when he gets back here, now he's lining up with this guy back here, because this thing is traversing past the proton, and so he flattens out some more back there.
And then when he comes around the front, he's flattening out more here.
And so constantly his procession is flattening out like this.
And then when the radiation is turned off, he flips back to where he was initially, that is processing around an axis that is parallel to the external magnetic field.
Okay? This is the fundamental mover in the magnetic resonance imaging machine.
And this description here, this is magnetic resonance.
Okay? It's previously called nuclear resonance, but for political reasons I presume, the name was changed to magnetic resonance to not, you know, flip people out on the table, so to speak.
And then people get a little bit more, you know, weird, you know, stepping into a nuclear machine, you know? So, okay, so let's take a look at a group of hydrogen atoms.
So the body has a lot of hydrogen in it.
We have a lot of water, as a result, H2O.
We have a lot of hydrogen.
And so initially, all these hydrogen atoms have dipole movements that are oriented in all these different directions.
It's just totally random.
But then we apply an external magnetic field like so.
And all the atoms, all the protons, line up like so.

Okay? And so they're rotating, but they're also processing about the an axis that is parallel to that magnetic field.
But then we emit radiation that is lateral to that procession axis.
That radiation comes in and slattens them out as discussed previously.
So it's rotating, it's processing around like this and rotating, but then it's flattening out.
And then when that radiation is turned off, all of the atoms, all of these hydrogen atoms, flip back in this case here, to this direction.
And then going from here to here, wherever they flip back, you can think of it as a spring.
They're being pulled back.
It's like cocking a spring.
And then when the radiation is turned off, they all flip back to where they want to be, back to here.
And radiation is emitted.
And that radiation could be detected and accounted for, and to form an image.
And so in 1973, there was a breakthrough by a man by the name of PC Loverberg, which is his name.
And he said, okay, what if we take a human and we stick him in this tube here, and he didn't do it with a human, he did it with some other stuff, obviously.
But that extends to humans, and obviously has.
But if we stick a human in this tube, and we take this superconducting magnet that is a very strong magnetic field, in the neighborhood of five Tesla.
And so we have a magnetic field along the axis of this tube, that all the protons will line up like this.
They'll be doing this number, right? Okay.
And then he said, okay, well, what if we apply a secondary magnetic field that will produce a field gradient so that the magnetic field is increasing along the axis of the tube? Okay.
And then we can, so we have a changing magnetic field along the axis of the tube so that the one more frequency has different values along this tube here.
Okay, so the one more frequency.
So you come out to say 1.3 meters, you come up and you find the B value.
You know, this is some B value, we call it B1.
And this would be, let's say, B0, B0, yeah, we're good.
Okay.
We call this B1, all right? And some value greater than B0.
And then you come here and you plug in B1 here, and you find some new little more frequency.
Well, then you take radiation and I made it into the cavity and only protons that are, that are processing at that frequency will emit radiation.
So if you look, if I've drawn this right about this on purpose, so if you translate down here, only atoms, only hydrogen atoms that are in this slice here, will emit radiation.
You turn the radiation on, you flatten out the procession axis, you know, the procession axis is flattening out, then you turn the radiation off and they spring back whenever they're spreading back, they're making radiation.
But the flattening out of those procession axis only occurs in this little region.
It doesn't occur any of these other regions because of the field gradient is increasing like this.
So these all have different, more, more frequencies, right? And so they resonate at different frequencies and so will only resonate at this specific frequency associated with 1.3 meters.
Okay? And that's it.
That's the basic idea.
Now this, this thing has gotten complicated, you know, there's, there's all these, you see this, you see the saddle coil here? This is the secondary coil.
You used to create this magnetic field gradient.
But electrical engineers have come up with a variety of different geometries for coils.
So they can not only, they can not only modify or have an electric field gradient in the, in the Z direction, but they can also have, and I think as a zero, if I said X, pardon my, my Gaff, if I said X, but they can not only have a

magnetic field gradient in the Z direction, but they can also have one in the X direction and the Y direction.
And so you will have just little bit of cubes of matter in the person emitting radiation.
Now only parts of the body that have water in it will emit radiation.
And so places where there's a lot of water and tissue and so forth will, you know, will emit a lot and you'll get a white picture right there.
But places like bone where there's not a lot of water, will emit, will emit a lot of radiation, and so you won't have much of an image exposure right there in the data that's collected.
And so this is the general, this is the general idea.
Okay, see you next time.
So that is an excellent mini lecture.
And you may consider if you could present such a lecture for X, A, C, T or nuclear tomography.
That would be nice.
The presentation scale is so important.
And I don't expect you understand all the gentlemen's side, but I would advise you to view multiple times.
And after you learn all the M.I.
staff or finish reading the chapter, I suggest you watch the video again.
See if you can say, understand 95% that will be very nice.
Okay, so far you have a general idea, although several places still look a little confusing, but you have a general idea how we do our imaging and hope, you will resolve your puzzle and the puzzles and the guide, more understanding as time goes by.
And next, we will review what we learned, some of MRI medical, physical staff.
We learned the data product.
And we mentioned multiple times, the inner product, the dot product, is the area of data that it says.
So, the dot product has a geometrical meaning.
So, we have two vectors V and W, you do inner product or dot product.
Basically, you compute the area of this save, this is a parallelogram, so you get the area.
So, this is a very cool and fancy mathematical operation.
And you know the dot product has a system or browser operator called cross product.
And this is also very cool, you have a vector, and then you do cross product, every cross B, and your guide, your guide, your results.
In this case, the result is not a scalar vector.
And the vector is perpendicular to the planes, bound by vectors in the B.
A very badly defined cross product, the inner product, we learn a lot of the saved geometrical meaning, projection, and a lot of things, you become little familiar with the dot product.
A very badly, now you're getting the cross product.
And then we have really good reasons, and the physical reasons are absolutely essential.
So, you see this animation, so we define torque, and the torque really changes so called the angular momentum.
And the linear momentum, angular momentum, are important concepts, and let's forget about this moment, okay, this is the parallel, this parallel, the relationship between force, torque, linear momentum, and the angular momentum, and the all-animated, in this small icon, and we know the linear momentum, so we have a mass, and the moving along certain directions at a velocity V, so, mass times V is what we call linear momentum.
How can you change linear momentum? So, that means you need to change the velocity, okay? Then you need, according to the order of second law, and the momentum can be changed, the change of momentum, or change of V will be acceleration.
So, the linear momentum, the force of all the derivative, really applies to the velocity.
The velocity is the distance to the time, first of all, the derivative.
The second order is acceleration.
So, the linear momentum, the time rate is the force, okay, fourth is the reason

why linear momentum can be changed.
And now we're talking about rotation.
So, talking about the rotation, so the linear momentum becomes angular momentum.
So, linear momentum is this P.
So, you cross product of this R, so R, you cross P, then you got the angular momentum.
Now, you want to change the angular momentum and you need half the torque.
And the torque essentially is the same thing as the force, but you have this distance R, taking into account.
So, the distance R lines like the cross force that gave you torque.
The torque is the reason you change the angular momentum.
The angular momentum is the rotation sin.
So, you just try to steer it a little bit.
You just raise the wave a lot, so that is the measure that I talk.
And if you interest enough, then review the physical content.
Some text book or Google, and you will see the angular momentum can be changed in a similar way.
So, here you have linear momentum change and the by force.
Here, the angular momentum can be changed by torque.
And this is a secondary relationship.
Really derived from Newton's second law.
So, Newton's second law is more fundamental.
This is force, you change the linear momentum.
But now, you're talking about rotation, and you have force, the distance, the cross force, that is torque.
The torque changes the angular momentum.
So, this is the relation.
And if you want to know why the derivation isn't too hard, you can review yourself.
But now, this is the introduction of the concept.
So, the cross product is needed to define angular momentum, to define the torque, and to have another version of Newton's second law.
Just like I often call it, I made the first derivative of linear momentum is force.
Now, the first derivative of angular momentum is torque.
It's really good analogy, and there are essentially the same thing.
Just like you need to do a little bit of mathematical steps.
And I have two pages that I put in the green line, so I don't need to worry too much.
But if you do want to know, just be patient for a few minutes, maybe 10 minutes, 20 minutes, no more than 20 minutes, you will see this relationship indeed derived from Newton's second law.
So, so much about these fancy cross product, the cross product, the bottom product, they are pretty much determined, like field.
So, we will come to that later, later.
Again, review a little bit of high school thing, and just go quickly.
You like treacle, false, you have chargers, and the same chargers, and the different chargers, in the other, they determine the nature of the chargers, they determine how they play together, they either track it to each other or they repel them away.
And like, like, like, like, like, like, and the, the magnetic bars, you have two polarities, and the, and the ice, two poles.
Again, like poles, they repel each other, they different poles, they attract each other.
So, you have two interesting things, and you have similar interplays, and the same thing, same expertise, they don't need each other.
You have different expertise, you want to collaborate, they are attracted, into a team, so something like this.
And then, our worst is a big magnetic field.
And the stress is not very high, and the major is a Gauss, and the Gauss half Gauss, but for MR imaging, we need a much stronger magnetic field, and we use unit Tesla.
One Tesla is 10,000 Gauss, this is the 10,000 times stronger than Earth's field.
This is the general knowledge.

And then, we have more interesting things, and we talk about electric and magnetic forces, and separately, they are really connected, in an interesting way.
So, electrical current can introduce magnetic field, so you send current, the serial coil, the magnetic field, they will be build, okay? So, this is one way. And then, they are, with the opposite way, magnetic field can introduce electrical current, you have a circular loop, and you try to insert magnetic bar, or you take it away, and the easier way, the field in the loop, magnetic field in the loop, will be changed, then, the electrical current will be introduced, and the field, the magnetic field, introduce the direct, introduce the electrical current, will just try to counter-react to the field change, okay? You see, you try to increase the field, then, introduce the electrical current, they will try to reduce the tendency, okay? So, this is just the, to tell you, electrical field, and the magnetic field, they can produce, they are, they interact, they are, they are very interesting function, and the Maxwell, and the believ, the, the, the Newton Einstein, that Maxwell, these, these guys, the, the greatest, the physicist, and the major contribution, by Maxwell, is the so-called Maxwell equation, okay? And then, again, I put a green, this is the, green button here, I do not require your understanding, but the higher I will really, Maxwell equation, characterized, electron magnetic interaction, all the things I mentioned, the charges, they, they, just generally, the electrical field, they interact in the way, this, electrical and magnetic field, they, in joules, they have everything, characterized by this side of, equation, and the graduated level, of course, is, and I, actually, no, but, for you, just note, we have a nice set of, equation like this, and the operator, you, you, you, you see, inner product, cross-product, so, these two operators, are used to, to define Maxwell equation, so they are very important, and geometrically, the inner product, really, just, how, is it, to determine, the divergence, and how, you think about, some of the pixel, what, what, how, the vector field, the flow into, all, all the words, so that will be, something we call, divergence, and the, on the other hand, the cross-product, and just how, you calculate, so, the curl, and the inner loop, and the looping current, or, just, think, the, the lace-on circle, you drive the car around, this circular, quantity, and you, you, you know, the divergence in the curl, at every point, and you're pretty much, determining the vector field, so, and the, you, so, greeting operator here, this, this is a greeting operator, dot, this vector, the electrical quantity, B is a magnetic quantity, the magnetic field, so, you're using the, greeting operator, acting upon, electrical, electrical, and the magnetic components, and then, you're using, inner product, cross product, you have a way to find the rule, then, you generate a, you like to, magnetic waves, that's very cool, so, this is a fundamental equation.
Furthermore, we say, if the, electrical charges, moving in the magnetic field, the electrical charges, will feel false, that is called, Lorenzo false, and you know, graduated lecture, and we argued, in the case, that Lorenzo false, is independent, or derived, can be derived from, Maxwell's equation, and the conclusion is, that Lorenzo false, can be derived from, Maxwell's equation, so, Maxwell's equation, is really self-contained, it's just the governing rules, operating together, that's all you have to do, is to, also, operating together, that's all you need, in terms of, EM waves, and the interactions, and then, we need, know, these concepts, at least, these concepts, EM, theory, Maxwell's equation, electromagnetic interactions, waves, excitations, those things, should not sound, to unfamiliar, to you, so, so much for the first part, next part, we really, be more, consistent, in the ways, your text book, the, the, the, I'm a chapter, so, first part, I give you some, physical, foundational, stuff, and we're talking, we are, we are talking about, angular, momentum, magnetic moments, and the form, quantum, mechanical, is, point, reveal, and we're talking about, magnetic, magnetization, or I'm a vector, the bigger I'm, so I'm a vector, and the, the four-name, is, magneticization, and the form, a classic, point, reveal, so that's easy, to understand, the power, sequences, and so on. Very, interesting, and somehow, mystery, called, precision, and we're, explain, little bit.
So, all these things, together, form, I understand, the rest, part of the, I'm a chapter, okay? We've revealed a bit, high school chemistry, this is a, typical, atomic structure, and the outer shell, you have a bunch of electrons, all baking

around, all you think, electrons, they should be with, according to certain probability, they should be with it.
And the other side, so you have electrons, and the, in the nucleus, and they will have two, major particles, and the protons, and the neutrons, and the protons, carry positive charges.
Neutrons are, like, like, particularly, neutral, and they, they, small range, and they have strong forces, try to hold, them together.
But, yeah, I'm afraid, they see all the positive things, guiding together, they will pow, each other.
So, the strong force, and the E-M-4, they try to reach the balance, so you have, they are stable, structure, and we, minding this type of interaction, in the nuclear, imaging, a chapter, but anyway, this is an overall structure.
And interesting things, is that, the proton, the positively-character, the small particles, they are, not stable, either way.
They have a, most, probably, called a subaining.
This is, keep, this subaining, pretty much like, like, a subaining top.
So, because they, they're charges, they're subaining around, so we have, electrical, lupus, okay, the electrical lupus, really, generate a magnetic field.
So, these are lupings in, and they, they're, field, o-magnetic moment.
So, we can use, the simple, meal to represent, the magnetic moment.
So, this is only for, one small proton, in water, molecules, for example hydrogen.
And they normally, all these protons, they're, the magnetic moments, they point in, random directions.
So, all of, they do not have, nautical fact.
And, in the, in the chapter, and we, at least, have a few formulas, and that is, directly, we live in the two, I'm I, so two key concepts, you need to know, angular, angular moment, p, and angular moment, that's just, you, you know, the mechanics, stuff.
So, the proton has a mic, it's rotating, and then you have, angular moment, there's, like, water, x, you have, angular moment, you can use, toe, you can use, toe, try to, just, change the angular moment.
So, this is a mechanical thing.
And, the proton, has not only mass, but also, positively, positively, positively charged.
So, it also has, you like to, magnetic property, calculated, like, magnetic moment mu.
So, interesting thing is that, these two quantities, are really linked together, in a rather simple form.
So, mu, equal to gamma, times p.
So, this is an important link, between, mechanical, and the electromagnetic stuff.
So, this is, very cool.
And, there are some, other, formulas, a couple.
So, the, p, angular moment, cannot take, continuous, quantity, according to quantum mechanics, we have to, you, I, surprise, p, in terms of, s-been quantum number i.
So, you read, you just, you know, and the, for proton, of all, interesting.
And, the, the value of i is, just half.
And, so, the p, will have, this formula.
And, then, the most important thing, is, here.
So, mechanical, and, electro-magnetic, quantities, are linked together.
And, they can't point to any, they're exist.
But, once, we have the, magnetic, moment, in, magnetic field, and we would have, longitudinal components.
Again, the longitudinal components, cannot be arbitrary.
And, in classic, mechanical point of view, it can't be continuously changing.
But, now, we need, I mean, I did a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, a, and you'd just read to, you'd just read to, so, I actually delighted by 4P.
So we're talking about the undermoment.
So this is the rotational thing.
And also we talk about the energy level.

When you put these meal things, these are the magnetic moments of spinning protons into magnetic field.
And we have different energy levels, depending on how the spinning protons is aligned with the magnetic field.
And they can only take two positions.
Because here, I mentioned that you only have two possibilities, plus and the manners.
Gala actually delighted by 4P.
So if you take a manners value, that means the energy is lower.
So you are in parallel state.
And the other state is higher energy.
And they're called anti-parallel.
So easier anti-parallel or parallel.
And the electrons and the protons will be lying up with the mean field.
Easier in parallel or anti-parallel.
And the energy level are different.
So this is a classic analog.
So we put the magnetic bar and you rotate.
And the certain direction is preferred.
And you rotate around, but you need to work.
So the energy will be stored if you change the magnetic moment.
OK.
And the anti-parallel and the parallel and the arguing different energy levels.
So let's compute the difference between the two energy levels.
So the lower energy level in parallel state under the higher energy level, anti-parallel.
And the what's the difference in the performance of the certain calculation?
Because you already know the energy.
The mu Z by those two states plus and minus.
And you calculate the difference.
So this is the plus and minus, the negative energy level.
So you calculate the energy gap.
So you find that by increasing for point line.
So this is for single spitting proton.
And how many protons are in parallel state? And how many in anti-parallel? So we have some mathematical, physical models.
And the Boltzmann increasing, this is the problem of the distribution.
So you have the Boltzmann distribution.
So number of anti-parallel spitting protons divided by the counter-parallel for parallel state.
And you got this formula.
And you read the formula, you read the little bit, you can compute this difference between parallel lower energy status, little more.
You're later to higher energy status.
So you do the difference, and you can compute.
And the result is that the difference is rather small.
And the rather small, there are some models.
Maybe only few, every one million protons, only few of them, really just the difference only few of protons.
Meaning the number of protons in parallel, only slightly more than those in anti-parallel position.
So this is a tiny difference.
So just all these models.
And these slices, the Boltzmanns, are earlier.
And once we are talking about precision, we will come to that rather soon.
And you need to understand the vector, magnetic adjacent vector, in the B field, magnetic field, we'll do this precision motion.
And the pretty much like spinning top, you see.
And later, I will show you more way.
So why is that? I need to know the Newton's second law, not just that I'm equal to I-A, but in the context of rotational staff, in the context of angular momentum, and how you derive the relationship, the angular momentum change is just to torque.
And that's nice.

So this is a slice.
You really see what I told you so that.
You have the relationship derived here.
And again, you see the green button.
So I will then go through this.
If you are interested in the way that, if you are not interested in just trust me, D-R, D-T equal to torque, I-O is the angular momentum.
So look at this.
This is the classic example, same thing for I-M-R, I'm the vector precision in same thing.
So you have a classic spinning top, the key point rotating along this direction.
OK, then you compute, you can figure out your direction of the reason.
I-A-R, OK, this is angular momentum.
You have I-A-R, OK, I-A-R, OK, keep moving, keep rotating this way.
And it's just like an object, keep moving along the direction.
Every moment of reason, no force applied, it will keep rotating, it will keep moving, everything, keep moving along, OK.
But now, the linear motion, if you have fried same force, it will slow down, OK.
If you have the force, the velocity will change.
And the localized is angular momentum.
And you have a gravitational force here.
And this is a mass center.
You have a base in R.
So R cross R, R cross R, give you the torque, OK, you need a cross product here.
You do R cross R, then you have a torque towards the screen.
So gravitate, answer a torque about the pilot.
So you have this torque, compute, torque towards the screen.
So this is torque towards the screen.
So the angular momentum, this R is this way.
Now you have torque.
This is torque perpendicular to the vector R into the screen.
Then you will expect a change in R vector.
So delta R will be perpendicular to model R, this is orthogonal.
And the base perpendicular change will, this perpendicular change, OK.
We introduce the precision, this is doing this way, OK.
Like a subending top, and then you think that the subending top, and then we will fall down to the ground, no, either we just keep doing this.
Why is that? Because this torque is orthogonal, the torque generated in incremental change to the vector R.
The vector R and the change of vector R, they are perpendicular to each other.
Then you have circular motion.
This is actually not that hard to understand.
Look at this, OK.
You know the satellite orbiting around the virus, and the moon, never for falling down.
And that's more around the virus.
One of that, because you have these centripetal force, centripetal force, generate velocity, change.
That is actually the reason.
The acceleration is perpendicular to the vector of the satellite or the moon.
So you have a vector, it's in your vector, is not in the direction, no object, it's perpendicular to the vector.
Because there is perpendicular to the velocity vector.
So we have the velocity vector, we will not change it.
We will not change it's magnitude.
Only change the direction, where you have circular motion here, where you have in this angular momentum case, and you have the circular motion as well.
The vector moving from the direction, then the change is a orthogonal, toward the direction of the vector.
Then the vector will just do circular motion.
So that's the key point to understand this.
And you have a text book, you see the analogy.
So on land, you have magnetic moment mu, and the mu, this is the circular motion.

On the other hand, you have spinning top, you see? If we were not full-down to the ground immediately, it just do this circular motion.
And this is not easy to understand, but this is what indeed, correct physically.
So now let's look into more detail.
Water is the precision frequency, how can you compute it? And we have a slice here.
And this is go, screw quickly, and you can review yourself.
So the magnetic moment mu, sub-diagonal to magnetic field, B-0, so mu, again you need a cross product, mu cross B-0, and a generated torque.
The total is the reason for the angular moment, for the rotational angular momentum to change.
And here the P is angular momentum, and the change, first the derivative, this is back to time, is due to the force.
So the angular momentum is a classic mechanical concept, because the proton has a mass, it's keep rotating.
But because the rotating, it has a, because it is a positive charge, and the rotational motion generated electrical current loop, the current loop is associated with magnetic moment, the magnetic moment, sub-diagonal to the magnetic field, will generate the force.
And this torque, or the force, essentially is the lunge force, and it man's in the order.
Just like I've equal to M-A, when you're talking about rotation, things, and the serial field stops, and we will have so-called D-E-R-D-T equal to torque.
And here you have torque, you'll torque essentially due to moving charges.
This is the moving charges going circular motion.
And you can calculate, based on the lunge force, you can find the force of the torque, this circular, circuiting current circles, with the field in the magnetic field, B-0.
So you have torque here, and the torque introduced, the change of angular momentum.
And the angular momentum is directly, is linearly directly proportional to the magnetic moment.
So everything, link to the diagonal.
So really, through the mechanical things, then you can manipulate magnetic moment, this way.
And then you just see, you have this angular momentum, P, and the square root into magnetic moment, mu, okay.
Then this is a sub-drite to torque, I could surprise you here.
And then we'll, we'll, we'll, according to this relationship.
So this is a small angular change, sign D-5.
So think this is, just change the little bit, the, the tape of the, mu like to, or P like to, change the little bit.
So the D-5, sign D-5, it's just D-5, because D-5 is so small, you call it, this is D-P, so small change, you do to torque, okay.
Then the one you got, this is P, sign, say, that's the radius.
So you got this relationship.
So it's just to do, the relation, little bit.
So you just, you have D-5, you're more, you're more D-P, to the left side, then you have, like, more here.
Sign D-5, is D-5.
So more this D-T over here, you have D-5, it's just to do, little bit.
Simplification, you got this one, then you just got this, the last line, you can sort of, sign, say, sign the P, so you see the angular frequency, is proportional to B-0, basically it's a scheduling factor, gamma, gamma is, it's some constant, so it's a g-roll, called a phase-end, so you see the precision, frequency, proportional to the field of the strands, it's stronger field, it's being faster, and the V-Core field, it's being little slower, okay? So this is a precision of frequency, nice to know, and now let me show you this, nice precision demo, then you can have some, right, okay? It's much easier to demonstrate procession, that is to explain it.
Miss Jasko, motion around the stand is procession, it reflects the composite of the downforce, which is gravity, and the angular momentum around the axis of the spinning jasko.
This wheel will process about the string, due to the downforce of gravity.

If I increase the downforce by adding the weight of this wrench to the axle, notice how the frequency of procession increases.
This is precisely how frequency encoding works, for hammering imaging, because the frequency of procession is directly related to the strap of the magnetic field.
Okay, let's continue.
So we'll show the nice and move a loop, and the precision is very fascinating phenomena.
I remember I read some block of positive, saying I think by a few words, I'm going to show you the same thing, I'm going to show you the same thing, I'm going to show you the same thing, saying I think by a physics student, he said that he feel easier to understand the spatial relativity than this precision phenomena.
But if you follow the key point that I give you, and I think the precision phenomena is not any harder than circular motion, of satellite or moon, it's same thing.
It's just follow the vector, the direction, and the node is second row, and you understand the idea.
I'm a star for later data tricky, so you need to carefully review the concept, multiple times, then you get to know the beauty behind the spinning and the precision and the pulse sequences.
Now, the title of this slide is Magneticization.
What I mean, we know we have been talking about magnetic moment of individual potions, and we have many of them, yet in the field, and the majority, slightly over half, really in the lower energy state, lower half in parallel position.
And slightly less than half, in higher energy state, and the empty parallel state.
So shown here, so we'll have slightly more towards this direction, slightly less than half opposite direction.
Okay, due to quantum mechanics, and these magnetic moment, cannot alter the line up, can only take one of the two potions, and this one, this one, this angle can be computed by quantum mechanics, something about a 50 degree, I couldn't remember.
But anyway, so because it's not over the line up, so make an angle in the field, and it's up drive to two precision motion, because the reason I explained earlier, so do the precision motion, so shown here.
Okay, and we can, because these are vectors, so we'll have one vector, this way, the odds are vector, you know, all opposite directions, you're not effective, they cancel out.
I mentioned the lower energy spectators, the protons in lower energy state, slightly over, slightly more than those in anti-podile position.
So you're talking about, might fact, then you have a few, every meeting protons.
So this is the pointing to this, parallel position.
So you have a few parallel magnetic moments, precision rotating this way, for every one meeting protons.
Okay, so all these things together, pointing different directions, but we all have a positive, a lot of material components.
I did a parallel form a single vector here, this is called magnetic-z-z vector.
It's a vector, you call it a vector, it's just called magnetic-z-z, you know it is a vector, or you call it I'm a vector, but this concept will be utilized widely in later part of MRI, a meeting modality.
Okay, so we are moving from, proton-like discrepancy, so that's the problem, and the two, collectively, five magnetic-z-z vectors, okay, here.
So after this point, you can forgot about quantum mechanics.
It just treat as a classic vector, and the once the vector stops like two-folds, and then it will move continuously, you can turn, you can flip it to any angle continuously, so it just like a spinning top.
This is very convenient for our power sequence design, and the general understanding.
For practical purpose, you really don't need to guide into the quantum mechanics concept, whether it may be not, then we still might say quantum mechanics.
After all, quantum mechanics is the most fundamental theory now.
But the majority, most times, and the classic discrepancy will give us good, am I amazing, sequences, and the solid, and the solid, okay.

Now how strong is it? This I'm a vector.
What is amplitude of the I'm a vector? We really need to talk about, we really need to take the light, if I could, what is the light, the surplus, spinning photons, in parallel position, and if we calculate this difference before, remember the light, the tidal, the tiny, tiny difference, and the non-linear, that we can compute.
Okay.
This is a total number, the princesses, this is a total number of night protons in parallel state.
And then, you just use this, tiny difference, scale, this formula, gamma, i, over two times, so that's the formula remains before.
So for single protons, you have a mu vector.
I surprised as, gamma, i, over two times, but now you have this, not the last number, like every medium, protons, you have a few, so you multiply them, to get, you have many, many medium, these still not to bad.
So I'm a vector, i-up, you'll also call it m-0, magnetic adjacent, I surprised, this way.
Okay.
So, every just a line up, that's fine.
reunity, okay, that's fine.
So, the magnetic adjacent, is in the stable, state.
Only the component, m-g equal to, m-0, and the transverse component, is 0, and m-y is 0, m-x is 0, because it is a relatively high up.
And if you look at the individual protons, they still have, parallel, antipowelal, and the point in two different directions, but now we are talking about, not, in fact, magnetic adjacent vector, and the more other components, except the longitudinal components, so this is a steady state situation.
Okay.
So, so much about, the physical foundation, very good.
So, you have solid the physical foundation, i-m-i-m-d, very much, physical stuff.
Okay.
You have solid the physical foundation.
And the next part, let me explain to you, how you generate i-m-i signal, okay.
Pay attention to max slice, okay.
We want to generate i-m-i signal, otherwise, you wouldn't know what's going around inside, okay.
So, magnetic adjacent vector, i-m-0, reflex, well-to-content, and also, little bit, little bit, because in the well-to- and the little bit, you have a lot of high-degents, and you have the subaining protons, okay.
You're talking about the 9-3, so there are some negative factors, whether all we present, as the longitudinal component, i-m-vagator, or how can you measure these i-m-vagator? And if you just leave it alone, you will not generate any signal.
It's just the standard, it's your model, whether you can now get a signal, out of the sample, or out of the patient.
Under the max line, this is the idea, say, electromagnetic induction seems the way to go.
By the i-m-vagator itself, does not give a change in field, because it's the natural magnetic induction, like a light-up, what I reviewed is you have a magnetic bar, input, a coil, or a static off, you introduce a field change, then you can measure, you can measure electrical signal.
But I'm like this, in the standard state, the field is fixed, that's all we are not in fact, the micro effect, this is the overload signal, and the everything is stabilized, in terms of engineering measurement, then how do we solve the puzzle? So how about we, just flip that and light-up? Making an angle, then we are not sure the components are also the transverse components will be increased.
And this transverse components will be being around, and the will generally can magnetic field, a changing field.
So this will meet our needs for electro-magnetic induction.
So this is the idea.
So, if you can flip and light-up, to have a transverse components which will produce a alternating magnetic field, due to precision, which will flip and

light-up precision.
So this is, I am a magnetic moment, a collective magnetic moment vector.
So, spending around magnetic field, will keep changing.
Then you can induce electro-magnetic signal, if you have a car or a new car, this is the idea.
So, if you follow this idea, if you follow this idea, say, surface in the many years ago, you could have gotten a very prize.
A very very prize for all I'm now, it really is the idea.
So you're putting some in the field, you have a vector.
While you're just the vector, you're using magnetic R-F-A-X-I-T-C then it will keep rotating.
Then it will turn the return alternating magnetic field, and then you've got a signal out.
Your analog signal, you know what's going on inside the sample.
So this is the idea.
Okay.
How can you perturb the balance? The vector is using steady state, is in balance, no field, the change, no magnetic field, is changing.
But if you flip it, you're just the break the balance.
Then you have nine-zero transverse components.
The nine-zero transverse components, they're not still.
It will do the circular motion called the X-S-A-X-P-L-N.
And this is certainly the most really means alternating magnetic field, and that can be measured due to Maxwell's equation, E-L-T-Magnetic In-Doxin.
Okay.
How can you perturb this is the flip that I'm right there? And we need to look at the energy difference between the parallel and the parallel energy back.
And they can be computed under the delta E, and we earlier increasing, I copied the E-L-T-Magnetic 4.9, is this a match.
It's not on this page.
It's an earlier line.
It's a 4.9.
Now we think we need really upside of the balance.
Break the balance.
We need a little bit of the balance.
And the energy is carried by radial frequency waves, either frequency alpha.
So, magnetic field is a frequency alpha, and the little chiral energy.
And the higher frequency, higher energy.
There is a famous formula in the Planck constant times frequency.
That is energy.
So, this energy should be carried by radial frequency wave.
So, this energy is carried by radial frequency wave.
All the same.
So, we look at the lower energy and the higher energy is the same.
So, you have this formula.
You are really in the data.
So, you see the frequency is equal to this march.
And you put the torque part, you move the torque part from right side to left side to left.
The torque part alpha.
That is angular frequency.
It is omega.
So, omega equal to gamma alpha.
There are no pre-season frequency.
It is identical to the frequency of the electrical magnetic field.
That must be applied for transition to occur between parallel and anti-parallel energy levels in the quantum mechanical model.
So, alpha alpha is a quantum mechanical point of view.
So, you have a low-energy level.
You have a high-energy level.
And you send a wave.
A wave is also particles.
So, you have particle-curry, same energy, enough energy.
Bring a atom, another item, bring a proton, from a low-energy level to a high-

energy level.
So, if you stop alpha-execitation, and this high-energy level can't return to the low-energy status.
Low-energy status is always stable.
So, the energy supplies will be released as a simple frequency alpha-circumul.
So, this is quantum mechanics point of view.
The same thing can be viewed from a classic point of view.
So, this I am a vector.
So, if you have a additional magnetic field applied along x-direction, you have an I am a vector, I am a vector is magnetic moment.
It's just a collective moment.
Then you have additional field along x-direction.
So, this is a particular B-1.
So, B- cross- B- cross- the magnetic moment.
Give you a total.
Total term is n-right-to- y-direction.
Immediately, this is more to that direction.
And this blue is n-right-to- n-right-to- n-right-to- n-right-to- n-right-to- n-right-to- n-right-to- n-right-to- n-right-to- n-right-to- x-direction.
So, R of x-direction has a 0 powerangelsä¸ scale.
The 4th central Inizationã Ÿã¸ This is the spinning thing, but the arm like this is the flab, making larger and larger angle.
If we keep the keeping in the precision motion, so the angle is larger and larger, but this is the precision, keep going on.
We're really half of this spiral down, not as half of a angle like this.
So the base and field needed to be perpendicular to the angle, I'm like that at any time.
So all of our bodies are not nice pictures.
And it is convenient to consider rotating field.
The laboratory coordinate system gives you a spiral trajectory.
But over you rotate.
This is the normal frequency.
And we wouldn't see this spiral, we wouldn't see, I'm like that.
Simply flab, the parallel to the x-ray plane.
This is easy.
So because you're using a rotating frame, you're like the new coordinate system, rotate.
This is the arm like that.
In the same normal frequency, the entire spiral trajectory is disappeared, and they only see the same polarity motion.
So you're back this way.
And this way is a lot of going on.
And you try to, you think, and I'm saying that, okay.
What's going on? Okay.
And remember the lecture, the first part, the gentleman explained, you signed the R of signals, and then you have some bending scenes going on like this.
And then you are a signal.
In the same frequency, as there's a precision frequency.
So the signal is also visible, as a lesson, for all of your R of x-ray pieces.
Once you're un-like, you're going to see a vector at this direction, the R of signal, a pulsar at this rate.
And I will be arguing the direction, pulsar at the back.
So the R of the solution, and we will, uh, precision frequency, other thing.
So the R of the exercise, that's the subaining, there's a larger, the larger R of an angle.
And the pretty much like a lady, and the keep pressing the door, so the force, as always, perpendicular to the plane of the door.
It's just keep moving, it's the way.
If you do not keep it, it's in you sometimes, the force sometimes, you drive, but you will not, uh, you, you will not have the uh, oscillation, the cumulatively, the positively, or you are not in a resonant, you will, you'll press out, you'll pull back, and the sense of you will cancel out.
So this is the, the general picture.
So, try to understand, the rotating form is really stationary called an A-

system.
And if you just, like a car, so, if you rotate it, the data, this is the precision.
Now you wouldn't see this model and you'll see that they are in a field, the RFX statistic, as a constant force applied and there is a constant torque, that's just the turn this I'm like to form 0 degree to 90 degree or more or less, they turn it over and because they are torque, they will change, they will change the angular momentum, they will change I'm like to direction.
Now we have a central concept, carbonic equation, carbon, blotch equation, and the blotch that really will show the name blotch and now they are going to go to the real price as well.
So all these are very important work, classic work.
The blotch equation is a carbonic equation for MRI imaging, this requires the resistance of an unvector, this is a rigid tool torque and the relaxation.
So first the first term of the right hand side, so the right hand side, I'm like to say, is that magnetic moment, the collective magnetic moment, it will change, why magnetic moment will be changed, and this is the same reason, why angular moment will be changed, because angular moment, or magnetic moment, they are changed because you have torque, right hand torque, because circling charges, the circular carbon, and the Hasse magnetic moment, magnetic moment, magnetic field, they will feel false, why they feel false, because moving charge will feel false, lo and false, due to magnetic field increase, so magnetic moment, field false, due to magnetic increase, and the moment cross magnetic field, and scale the diagram, water is torque, torque, and the false, they are same thing, just like in modern mechanics, and the linear moment will be changed by false, and the moment will be changed by torque, they are same thing, this goes to the nice everywhere, want to know, and here, the torque is due to the electromagnetic field, so I'm like to cross B, and the torque will change, the torque is the first, the first, I'm like to, because the torque will change the angular moment, angular moment, and the magnetic moment, the magnetic moment, they are linked together, I'm not saying that the first increase, I'm not saying that the remember data, is the linear and the p, linked together, that's the third increase, and you are MRI chapter, so this is part of machine new, really just to say, okay, the angular moment will be changed by torque, okay, so this is not the, not the same machine, but what's interesting is the second part, the second part is an empirical part, so the third, the system has a steady state, I'm like to, and the steady state, is one that I'm like to, line up, this G, I can say is it, so the only component available is G components, and that is, I'm 0, so that's the steady state, but if I'm like to, is it perturbed, is it flabbed, to some other angle, it will tend to lie up, and why it will tend to lie up, the classical analogy, like if you sign a ball rolling, and even nothing else is theoretically, you know, a deal or the, it will just keep rolling, infinite at a long time, but in reality, it will not happen, the ball will keep rolling, but you have, you have, resistance, you have, you have, uh, fraction, you have many other things, it will, will slow the rolling ball down, so even truly, the rolling ball, at the initial velocity, will become lies and lies, the person to zero, okay, it's similar, so once you have this precision, if nothing else, it will keep rolling on forever, just like your spinning top, even truly, you're folding down, okay, you're folding down to the ground, okay, the precision motion, precision, that I'm like to, and then we will even truly return to the lowest the end of this, that is, so from the current precision, I am of a T, where even truly pulls to lower energies, that is, I am zero, and this will be still, that by R, because I am zero, and I am of T, oh, right here, so there are a symmetric, and then it will slow down the, slow down the precision, and the, in different mechanisms, called T1T2, so this is just the overall equation, the fourth term has been explained, this is the torque, cause change in angular momentum, in magnetic momentum, the second term is an parallel term, and then we will, the, now in general components, once our level is, we will eventually become, and zero, this is, the reverse state, and the horizontal components, x, I'm x, I'm not, even truly will go to zero, so the horizontal components will, relax according to T2, and this will, relax according to T1, so this is, right here, increasing, if you, expand, you have to, you see, the longitudinal components, carbon by T1, horizontal components, carbon by T2, so this is a matrix, cause you need to fit T1T2, for longitudinal and transverse

components, respectively, and the cross product, and the little nicely, but if you, expand, you will have the components increasing, and they do not be, like this, increasing, but if you, on this time, the first line, will rise, will be, uh, easier, okay, will be, uh, will be, uh, straight forward, so this line, shows your, hard block increase, uh, is working, and then you see, you have, I'm like, uh, flippered by angle, all that, and the G components are, and the, the angle, horizontal components, becomes, I'm xy, and then, it depends on how you select, you, I'm xy, what I call, then it says name, and this, I'm like, uh, will be, will be, in precision, as I explained before, I have, uh, 0, then, no precision, I'm not, more accurate, I would say, 0, precision, even the angle, 0, is still, still, I'm like, still, I would say, still, in precision, this is because, the radius is 0, don't see, but it's still, just, just circling around, a single dot is, more, more consistent, to the physical understanding.
So, your flip, I'm like, in the, uh, rotating frame, in the rotating frame, so you're thinking, uh, uh, a diagonal, a diagonal field, along x direction, that will kind of flip, like, towards, like, this is, you just, longer enough time, the angle will be larger, and the larger, so this, I'm like, will generate an alternating magnetic field, in, in this, near by curl, and then you think, that, you know, the magnetic, magnetic moment, is, uh, magnetic moment, this is like, a magnetic bar, so over your rotate, a magnetic bar, the field, the certain, they keep changing.
Inside, these are, if a curl, if we generate, electric current, and, uh, amplitude, depends on, halage, and like, uh, halage, and like, it will be, depends on how many, protons, you have, the larger number of protons, larger, proton density, the larger, the larger, different, the tiny difference, there is a, there is a, so if you have many, there's a, honeyâ ¦! alteSa, verbess, so you cannot change very, you can't change your Protang density, so you can't change the first thoroughly, I can't really cope, The sebin, the sebin is a gulf from God.
If you deal with the sebin, naturally, the sebin can do anything for you.
So if you deal with the sebin, so you got a MR signal, you look into some deep secretory, some deep secret of the nature.
And even truly, your MZ will return.
If your time of signal for a while, you have an angle, you turn it off.
And even truly, the MZ vector will become MZ.
This is T2 effect, the energy losing out to the micro environment, to the matrix.
And the XY will turn to 0.
This is T2 effect, out of phase.
So we will explain that more later.
So the signal is detected by R of signal.
So this is the further clarification.
When MZ is philope, that R of signal, the XY, the transverse components, keep oscillating to induce sinusoidal signal by inducing in R of coil at a residual frequency.
And the high-speed inducing reaches at philope angle 90 degree.
Because when you philope, the M vector, into, completely into XY plane, the horizontal components, the transverse components, is maximized.
So you have larger signal detected.
And the M relaxation, and the will happen once the R of the power is off.
So I will rely on this B-0, the main field.
So the energy is absorbed, and the will be released.
So signal will decay to 0.
So this is so called the I-Fi-D free induction decay.
This is likely to go.
So the energy will be released, the signal will be recorded.
So this signal, the I-Fi-D signal called the NMR, NMR signal.
So all the signal from the sample together is an O-O signal.
So at the residual frequency, proportional to proton density.
So this is the different X-percent emission.
So these are few specialized, give you a complementary us-backed.
So we will then understand the free induction decay, how you detect, and you have O-O feeding, how signal will decay by T1 and T2.
So the signal decay, and the is important, because we have reflected T1 and T2

mechanisms, and that will give you good image contrast.
So last part, we have X-percent more about T1 and T2 mechanisms, and how can you measure T1 and T2 specifically? So this is just the O-O measurement, and we have talked about the pulmographic imaging yet.
So now let's look at why you have decay.
You have the decay because it's just like the rolling ball, why you slow down because you have R resistance, because you have a fraction between the ball and the ground surface.
But here, I'm going to flip it to precision, but eventually it will return to the steady state.
We will rely on this G-axis.
Why is that? Because T1 relaxation, flip the nuclear, we rely on this B-0, give energy to the tissue, become thermal things.
Okay, T2 relaxation, flip the nuclear, and the initial flip, to the lambda-axis, so along this, V-axis.
But quickly, there will be other phases.
I'm like there is a multiridimovigial, really a collective behavior, many, many small meals.
And some small meal may be here, some small meal may be there.
And the local magnetic field may be a little different, maybe field of B-0 is not that uniform, maybe some micro-local environment, some magnetic system, or this is magnetic ability, like between our notation, the notation of the ball, magnetic field, will not be uniform.
So, the stronger field, the faster the weaker field, the more precise the frequency is, the later layer.
Then we are starting to point to different orientation.
We cancel all the inside, that's called the outer phase.
And the coherent magnetic moment, gradually, quickly become incoherent.
So, the horizontal components will disappear.
They do not do good teamwork anymore.
This is T1, T2, T3 mechanism.
The NMI signal, proportional to proton density, this is general sediment.
But once you flip it into certain, transverse components, you generate a signal.
But this signal will not stay the same, because T1, T2 is like that.
And the signal will become weaker, and the weaker, and the weaker.
So, the NMI signal will be reduced by T1, T2, and T2 is larger.
What's T2 is larger? So, the T2, pure T2, is due to biological, physiological reasons, the speed in the interoxin are different.
And the T2 is larger, due to the energy nerves in the magnetic field.
And the magnetic field, not the uniform, because B0 can never make a perfect B0.
And also, some magnetic field, some in-horma genius, in-horma genius, in magnetic field, due to susceptibility.
So, you have one power graph in the book chapter, you can read.
And those susceptibility, and the candy-yous level functional MRI, like an enzyme, in biological tissue, there are some field in-horma genius, and the energy I've used.
And it depends on some ion component in the enzyme signal, the susceptibility MRI is very important for B0 in imaging.
So, the T1 effect, covering the weight, how the longitudinal components will return to normal, how quickly will it return to normal.
So, I'm just, you're flapered upside down, and then it will gradually return to normal, following the experiments of CRO.
Because the weight is proportional to the difference, it's very common thing, like what you show in nuclear imaging, and the human CPM imaging, you show the X-penninsal decay.
And the defacing, and the other X-pennins, and the inflator, and the X-pennin, and the X-pennin, and the X-pennin, and the X-pennin, and the X-pennin, along Y axis, and the over time, the small mirrors, the small magnetic moment, where the defacing, some do pre-season faster, the other is slower, so you just cancel Doom, so from the initial value, you go down, okay? And then basically, it can be, MRI semifinal model, and by T1 T2, the time constant, and following the X-penninsal, X-penninsal curve, and the, IMAX, change the time rate, and it's proportional to the amplitude, and the scale, that I T2, like that is for, N1, for the, down to two different components, and we need T1, so you just reveal

yourself, and the sum of values, you table for point two, you can read, and the P2 T2, and the T2 star, and the Manson, and the P2 T2, Jotus-Bins, Bint-Laxon, and the physiological, biological effect.
And the second course, is Jotus-Binsal varicence, in homogeneity, in the magnetic field, so we really see the field, why the field is not, homogeneity is, we really see, how to do the measurement, and the T1 measurement, can be typically done, by, we can do the recovery, and you use, a handy-duty, degrade, a pulse, you just flip, and like the upside down, and we will, gradually, we will reduce, and increase, and the magnitude, and eventually, we will return to the, turn it into, actually, then you get a value, and depend on the top, how quickly you, you can, how quickly the unwind will return to the status data, and it can be probed, which is tall, and this 90 degree pulse.
That's a visualize data, okay, you see here, you do a handy-duty, pulse, you flip, and like the, to manually, and like the, okay, as time, every, don't do anything, this will, gradually, return to the origin, to the stable, the, the status data, so this, and like manually, I'm 0, as it beginning, okay, every, sometime, in the middle, you flip it into, I survive playing, now you can see how large it is, you can do so, at different times, then you can trace the curl, and you do some log plotting, as described, you can really, is the made, of the T2, parameter, so you will, sorry, you can explain it to the T1, parameter, so this is the way, the inverse and the curl is the way to measure T1, and the higher measure T2, is the last slash for this lecture, this is very cool, so again, you see the graphics, and the next lecture, I will explain more about this trick, called the spin-eye curl, so that is, 90 degree pulse, you turn your flip, and like the, x,y, plane, say, alarm, that, x,z, and you will have, signal detected, i5, i5, T2 is a, major thing, this is a horizontal component, the graphite, the facing, make the, and like the, cancel out, and the amplitude will be, they will be smaller, but, after this time, you got quite a subsensor, the facing, and you flip, everything, this is the, this is the x,y, this is the problem, and then just use the cursor here, why, this, this is, magnetic moment, slow down, because it is slow, okay, this is a little faster, but after, 180 degree, this is the remaining slow, after, this is the action, slow, and then, until, it's time, this is a very, smart idea, all these, already, be faced, magnetic moment, they got real align again, so, they see, you easily have a signal, here a signal will be coming, rather smart, because it defends it here, right? so, you flip over, signal, signal, signal, signal, signal, signal, but, they've been certain amount of time, it's really aligned, you got an i-code signal, and then, you can, spin your i-code, again, in maximum lecture.
And your homework, is here, I think, you're too far today, thank you.