So diving board, a branch of a tree, balance beam-- what do they all have in common? It turns out that they all can be classified as beams.

In this concept, we're going to explore beams. So we'll explore how to design them, how they resist loads, where along the length is the maximum stress going to occur, where might they fail, and how they're supported, and much more.

So beams-- what are they? They tend to be long, slender elements which is nothing new. We've dealt with long, slender elements in structures. Our ropes and cables were long, slender elements. Columns tend to be long, slender elements.

So the main difference is how we apply the loads. With a beam, the loads are going to be applied perpendicular to the axis of the member. So the axis of the member runs along the length and will be pushing perpendicular. That's going to cause a bending deformation in the beam. And that's kind of the definition of what a beam is.

So if we contrast that with ropes and cables-- so when we dealt with ropes and cables, we applied the load parallel to the member. Ropes and cables can only carry tension. They can't carry compression, so everything was along the line of the cable and just in tension.

Columns were also long and slender. They can look a lot like a beam, but they tend to be oriented vertically, and the loads are applied parallel to the axis. So it's just a compressive force pushing down and pushing up. So the difference with a beam is while it might look like a column, it's typically oriented horizontally, and the loads are applied vertically.

So what happens when I bend this beam, and what types of forces are induced? This is a beam. I call it a simply supported beam. It's just got two supports on the sides. It has a grid on this beam. I think that'll help us understand what's happening.

So as I push on the beam, take a look at the grid. We should see that the lines on the bottom get longer, and the lines on the top get shorter. So the lines on the bottom, as they're getting longer, does that remind us of anything? It should remind us of tension. So the bottom is getting longer. They're elongating, or we're pulling on it. That's indicative of a tension force as opposed to the top which is getting shorter. So that indicates we have compression.

So in a beam, that's typically what happens-- well, a simply supported beam anyway with a vertical load. In this case, we have tension on the bottom and compression on the top. For other loading conditions and other supports, we'll get tension and compression in different locations, but we will always get tension and compression somewhere in the beam. So that helps us understand why beams have changed over the years.

So in ancient structures, where we use stone primarily, stone does a great job in compression. So we can push on stone, and it's very strong. But in tension, it's not very good. So it doesn't have a lot of tensile strength. So a piece of stone they used-- you know, think of Stonehenge or some of the large temples-- when they started to use stone for the beams or for horizontal spans, sometimes they called them lintels-- those tended to be very short. And that was because if they made the stone longer, it would just break, largely because it didn't have any tensile capacity. Couldn't carry much tension.

So most of our ancient structures out of stone were built out of arches or vaults, sometimes domes, which are great in compression. It wasn't until iron and steel were invented that we started spanning greater distances. So in the Industrial Revolution, we started making bridges out of steel and iron, beams in warehouses, so we could get bigger open spans and so the beams could span longer.

So it's all about tension and compression, but it's happening within a single member as opposed to previous systems that we've looked at where tension and compression were always in separate members. So even in a truss, we had tension on the bottom and compression on the top, but they were in completely separate members. And now everything's happening in a single member, in this bending member.

So one thing we talk about as engineers is if I push on this, I get tension and compression. I'll get a tension pair and a compression pair. Those together, they're typically equal and opposite, so we're in equilibrium. And they're generating something called a moment. So engineers will deal with a moment, sometimes called a bending moment or a couple. And what that is is a tendency for a force to cause something to rotate or bend.

So Hibbeler defines a moment as the force about a point or axis that provides a measure of the tendency of the force to cause the body to rotate. It can be about a point or about an axis.

OK so if you think of a door, as I open the door, it's easiest to open it at the doorknob. And that's because I have-- I generate a larger moment. And actually, let's try this. This is something I do in my class. So if I extend my arm, my arm can be modeled as a beam. It would be modeled as a fixed beam. It's only supported on one end, at my shoulder with a fixed connection.

But what I want you to think about is if I take a book, is it going to be easier for me to hold the book out at my palm? You can try this at home. Hold it at my palm? Or will it be easier at my shoulder? So give it a try if you can. So is it easier at the palm, way out further from my shoulder, or closer into my shoulder? Turns out it's typically easier to hold it closer to the shoulder, but why?

The book weighs the same whether it's out at my palm or near my shoulder, so it's not a difference in weight. The difference is the distance, so the further that book is away from my point of support, the more it's going to try to cause that support to rotate. And I have to then hold it in place.

So a moment is equal to the force times the perpendicular distance or how far that force is away from your point of support. So the greater the distance, the higher the moment will be.

So my arm is an example of what I'd call a cantilever beam, a beam with a single support-- tends to be a fixed support, a very strong support. Think of a beam stuck in a wall. It's going to have a nice, strong support in there.

Another common type of support system are these two supports that I've been talking about. And this would be a simply supported beam. They're all going to have tension and compression acting within this beam. So as I push on it, I have tension again at the bottom and compression at the top. And those would be in equilibrium, so they would be equal and opposite. The bottom half tends to be in tension for this type of beam and the top half in compression, and that's going to generate an internal moment. So like that moment of my force times distance on my arm, the book, internally, I'll get a moment.

So if I were to cut this beam in half, I would have an internal moment trying to resist this bending. It's still causing bending, but it's trying to resist it. And that force-- the force times distance would be the height of the beam in this case.

So there's two different ways a beam can fail. As I push on it, I can push on it and bend it too far, and that will typically cause a tension or compression failure. And that will be one mode.

The other mode is due to a shear force. So as I'm pushing this downward, there has to be a force balancing it upward, and we call that a shear force. So it's a shearing of the beam, and it could cause failure as well.

So a shear force is two forces that are parallel, but they're parallel and at a distance. So as opposed to in a column, when we push on two ends, those are two parallel forces, but they're acting through the same line. So if I have two forces acting through different lines which is what I have in a beam, it causes a shearing deformation. So that's what happens when I try to shear this book. So we start with a square, and then if I have a parallel force at the bottom and the top, I get a shearing deformation.

And this could cause failure too. So the beam has the potential to fail in shear so the force acting downward. If the beam doesn't have enough shear resistance to resist that upward, you'll get failure or it could fail in bending.

These long, slender beams tend to fail in bending, so the bending will dominate their behavior. But as the beam gets shorter and deeper, shear becomes a bigger factor. So they're both things we need to look at as engineers.

In this course, we're going to focus on three different types of beams. So a beam like this with two supports at the ends which I refer to as a simply supported beam. We'll also look at a cantilever beam, so that's the beam with a single support, a nice, fixed support on one end. And then a combination of the two would be a propped cantilever. So that's going to have the two supports, but one end will cantilever off the end.

I'm going to focus on these three types of beams, because they're all statically determinant which means the math behind them is fairly straightforward. If you get excited about statically determinate beams, you can go explore statically indeterminate beams, but that will require a little bit more math.

So what factors do you think will affect the moment and shear in a beam? So if we look at this beam is the connections-- do they make the biggest difference or the length or how much load I put on it? How about the shape? Does the shape make a difference? Or the material? This is made out of a plastic, but would it be stronger if it were made out of steel?

So experiment with the beam simulator and see what factors you think affect the shear and moment in a beam.