Biomechanics
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Lecture - 02
Statics FBD and EOE

Welcome to this class on biomechanics. In this class we will be focusing on introductory mechanics that is on statics and dynamics.

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As part of the introduction in this video we will be focusing on biomechanics which is an introduction to biomechanics we say we define some terms we define some terminology we define what is biomechanics. Then we introduce the concepts of statics and within that we focus on two specific concepts, one is free body diagrams and equations of static equilibrium.

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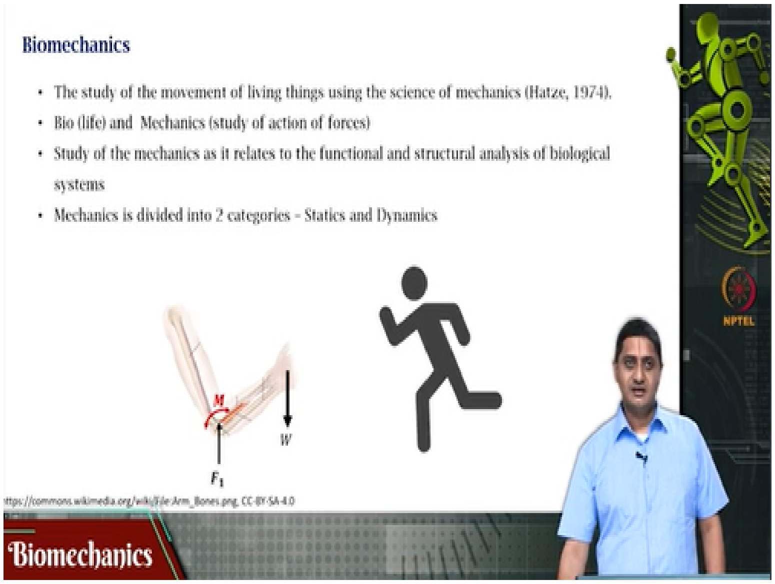

So, what is biomechanics? So, that biomechanics that word comes from two different sources one is bio which means it refers to life and mechanics which is a study of action of forces and movements that may be caused by forces etcetera. So, bio mechanics in general refers to the study of movement of living things and the related signs of mechanics. Sometimes biomechanics may start from cellular level.

So, cell biomechanics are tissue level by mechanics a group of cells put together is called as a tissue. So, sometimes tissue biomechanics may also be studied. Sometimes animal biomechanics may be studied how an animal moves and comparative to that animal how a different animal moves or comparative by mechanics different sources different types of this topic exists. In this course we will restrict our attention to the topic of biomechanics within human's movements.

So, we will not be focusing on animal or comparative biomechanics. We will not be focusing on cell level biomechanics. We will mostly be restricting our attention to musculoskeletal biomechanics in humans. So, movements and static actions performed by humans will be mostly the coverage of this course. So, another definition related to biomechanics is the study of mechanics as it relates to the functional and structural analysis of biological systems in this case as I said restricted to human system.

In general mechanics is divided into two broad branches called statics and dynamics. We will define what these are in some detail.

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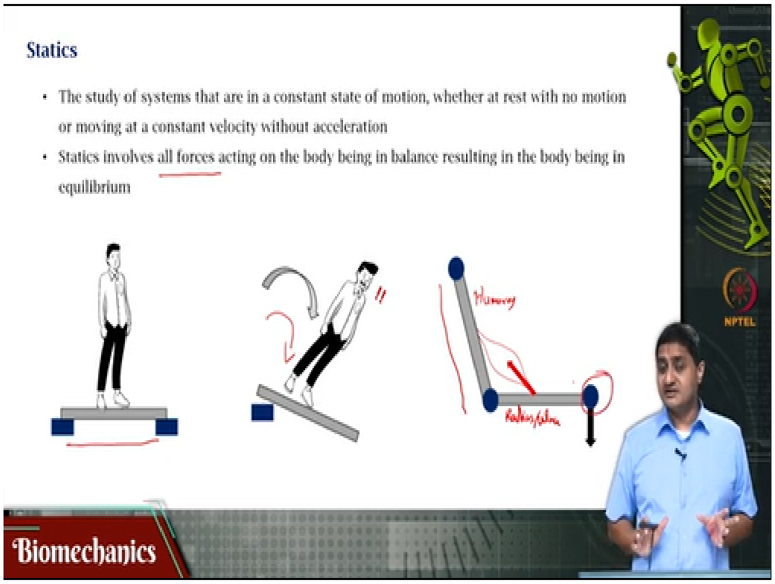

Statics refers to that branch in which a system is at constant state of motion or in other words it might be at rest or moving with a constant velocity that is it is not having an acceleration. Note that it does an object can be in static equilibrium but might still be moving. In other words, objects or bodies that are moving with constant velocity are also considered to be in static equilibrium.

This is a critical distinction because objects that are accelerating, they are not in statically equilibrium. That means that they are not just moving they are also moving with the you know non-zero acceleration. Bodies that are moving with the constant velocity have zero acceleration something to remember. In this course we will restrict our attention to objects that are at rest almost always are objects that are moving with constant velocity.

More specifically in this course we restrict our attention to objects that are at rest most of the time. So, statics and some amount of dynamics that we do will be restricted to geometry of motion or kinematics of movement. So, statics involves all the forces that are acting on the body being in balance that is resulting in keeping the body in an equilibrium. So, what are the various forces that will be required?

So, consider this pen this pen will have six degrees of freedom it can for example translate upward and downward or it can translate forward and backward can move towards you or away from you or it can move to my left or to my right. So, these are three translations that it can do. You know it can do that translation it can do that translation and it can do that translation. Also, it can undergo rotations about each of these three.

So, it can for example rotate about the vertical axis like this for example or in the plane that is parallel to the ground or the floor of this room like this. In this plane it is rotating right or it can rotate in the plane in which my body is visible in this plane. Or in the axis that is perpendicular about the axis that is perpendicular to this plane between you and me between or the so called anterior posterior axis.

We will discuss that in more detail for example this is that rotation that I am looking at. Then another rotation that is also possible is this rotation. I hope you will be able to see this. This is the other rotation that is possible which is about the axis that is passing through the long axis of the spin and this axis. So, that is this rotation that is possible, that is this rotation that is possible and then there is this rotation that is possible.

So, this brings us to six degrees of freedom that this will have. In this course we restrict our attention to objects that are in planar static equilibrium or whose actions are restricted to one plane or 2D. So, in 2D consider this person who is you know standing on this plank right this plank is supported by two bricks. For example, let us consider that this plank is supported by two bricks and is standing on this.

Suppose if you were to remove one of these bricks what will happen there will be a tilt that this happens that will be that that will happen. So, if this person is standing in equilibrium his weight is being supported by the blank and how is this happening that means because this person is not moving is just quietly standing. This plank must apply an equal and opposite force on him to keep him from translating downwards. So, this is what is happening.

We will see that in a bit more detail in the next slide. Consider the other case where I am having a weight in my palm in my hand and I am making that movement. That is a moment that is being that is being described here. You can consider this to be the humorous for example and this to be the radius element for example. Now a muscle can connect these two; right and if this object is to be in static equilibrium the force.

That is produced by the muscle must compensate for the weight of this object. That does not mean that these two are exactly are numerically equal. We will have to work it out.

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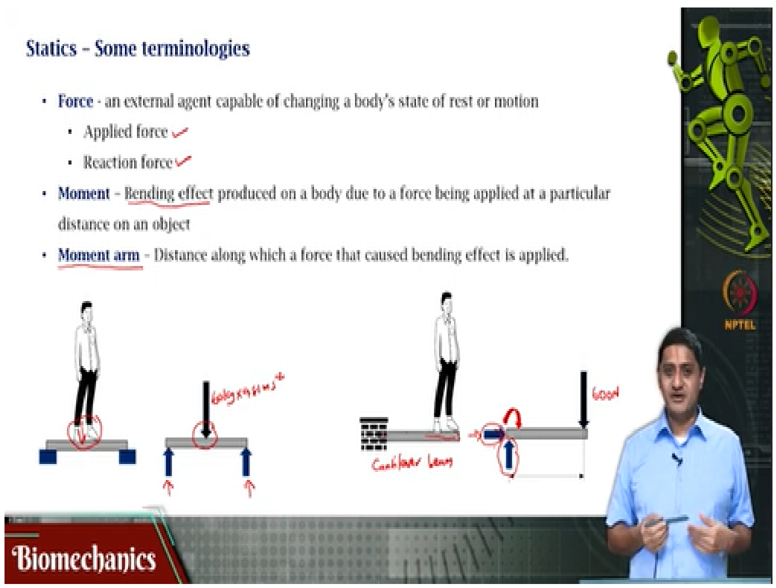

Some terminologies what is force? Force is an external agent that is capable of changing a body's state of rest star motion. So, something that can stop a body that is moving from moving are something that can make a body at rest to move. So, this force we can broadly classify for the purpose of this course into applied force and reaction force. What is the difference? Applied force is the force that is applied by the person or the object or the body under consideration and an external object or the body.

Reaction force is the force that is applied by the external agent or the body on the first body that does that is under consideration. What is moment? Moment is the bending effect that is produced on a body due to a force that is applied at some distance to this object or to this body. What is this distance that we are speaking about? From high school physics we know that this distance that we are speaking about is the moment arm or the lever arm of this.

So, this is the distance along which a force that caused this bending effect is applied. So, the perpendicular distance between the line of action of force and the axis about which the rotation is happened. Now let us take a simple case of this person who is standing quietly will assume that the total weight is acting through a single point. This is actually a simplification but for the purpose of this class we can assume that the force that his weight is acting through a single point.

So, there is a plank and there are two bricks. So, that way his weight let us say is 60 kg so that 60 kg times what is the acceleration due to gravity we know that that is 9.81 meter per second square, it is not so much approximately 600 Newton, a little less than 600 Newton is the force that is being applied by this person on the plank. But for this person to be in equilibrium the plank must apply this 600 Newton force on the person.

The plank must apply this force on the person so he can stay stable. How do you know this and if these two are indeed equal and opposite what is exactly this; can the mathematics will cancel out. But it is not so simple because these two are forces that are applied on two different objects. The person is applying a force on the plank that is the actual applied force in this case and the plank is applying a force on the person, this is the reaction force.

And this reaction force is applied of course at the point of contact here somewhere at the point of at these two points of contact. But then the plank itself is supported by these two bricks. So, this break you know is going to apply this first and this force and this brick is supported by the ground. But suppose the ground is you know having is not supporting or it is made of a body or an object that will you know undergo deformation a soft material.

Then it will not be able to supply that force in some cases depending on the load. But we do know that for example if it is a concrete floor, it will be able to support this force. So, based on this we know that because the person is not moving in either direction, we know that this brick is applying this force on this person that is why he is not moving or he is not accelerating in the up down in the vertical direction, we know this.

Now let us consider a case where a person is standing at the edge the same person is standing at the edge of a diving board here. So, this is a diving board this person is standing at the edge of this diving board. For the purpose of this class, I can consider this to be a cantilever beam and I can model this as a cantilever beam and draw the free body diagram. We will go into this in a bit more detail in just a few minutes.

So, I am drawing the free board diagram of this situation the person's weight is applied at the edge again. This person's weight is approximately 600 Newton. So, this is the free body diagram of the cantilever beam. So, there is a an axial force given by this and there is a transverse force given by this and there is a moment that is case. This is how do we know this because this cantilever beam will not allow moment in specific directions and will not allow rotations in specific directions.

Based on that we classify which particular object has what degrees of freedom and based on that we draw the free body diagram. So, we know this from physics and basic mechanics.

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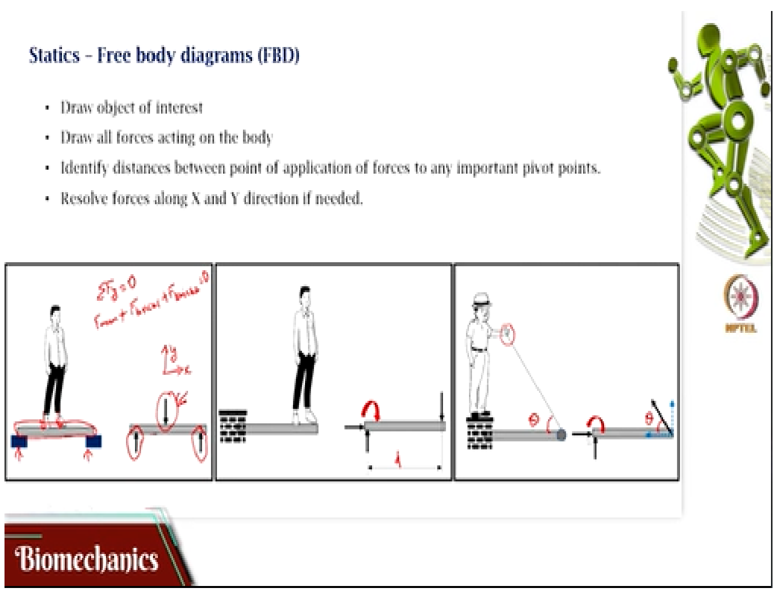

So, how to draw this free body diagram? What is a free body diagram? A free body diagram essentially implies that the body of interest is free from any external contacts. So, what you need to do is draw an outline of the body and for each contact that the body makes with other external bodies you replace it with the corresponding force or moment or force moment combination. So, this person is standing and I am going to replace it.

And essentially what is requested here is to draw the free body diagram of this plank. This is the plank; you draw the free body diagram of this plank. Well technically the free body diagram will have one force here one force here and two forces here for the two legs. But I am assuming that these two forces of the legs are you know they produce a resultant that can then be represented like this. So, I have this as the free body diagram.

So, this is the resultant force that is due to the person's weight that is this and the force from the bricks is these two. Note that depending on where you are standing on the plank the force from the bricks may or may not be equal and that makes sense. So, if I am standing at exactly the middle or exactly in the middle between the two bricks right then the force in the two bricks force applied by the two bricks will be equal.

However, depending on whether you are standing closer to a break that brick may apply a larger force. So, the only constraint about these forces supplied by the brick R what would that be let us assume for the purpose of discussion that this is an X axis and this is the Y axis. And because I know that there is no acceleration, we know from Newton's law F is m a and since a is zero sigma F is 0 that means there is no net force that is acting on this object.

So, I can say sigma F in the y direction for example is zero. Now if I am going to call this force as the force due to the man, I can now expand the sigma F y as force due to the man plus the force due to the brick one plus force due to the brick 2 is 0 for the given directions of brick one and brick two forces. Please remember that force is a vector and we do also account for the direction of the vector.

So, you say F man plus F brick one plus F brick two is zero that means essentially for the direction of the forces that are given the sum of the two forces applied by the two bricks essentially equals the force produced by the map. Now let us consider the diving board case and I am modelling this diving board as a cantilever beam. So, there are two forces and moment that is applied and at the edge the person's mass is supply and there is some known distance which is the length of this diving board.

Based on this I can write out the using physics and mathematics I can write out equations that keep this entire object in equilibrium. The other case is when a person is standing on one end of the cantilever beam and trying to keep this whole thing in equilibrium by using a rope or a thread is holding this in equilibrium. This is in equilibrium so this force this thread is at some angle known angle theta, I know how he is doing that.

So, that means that the force applied it turns out that the force applied on the rope or cable is along the rope or the cable. So, then this will be the free body diagram of this situation. So, there will be a force along the cable and the regular cantilever beam free body diagram or in other words two forces and one couple.

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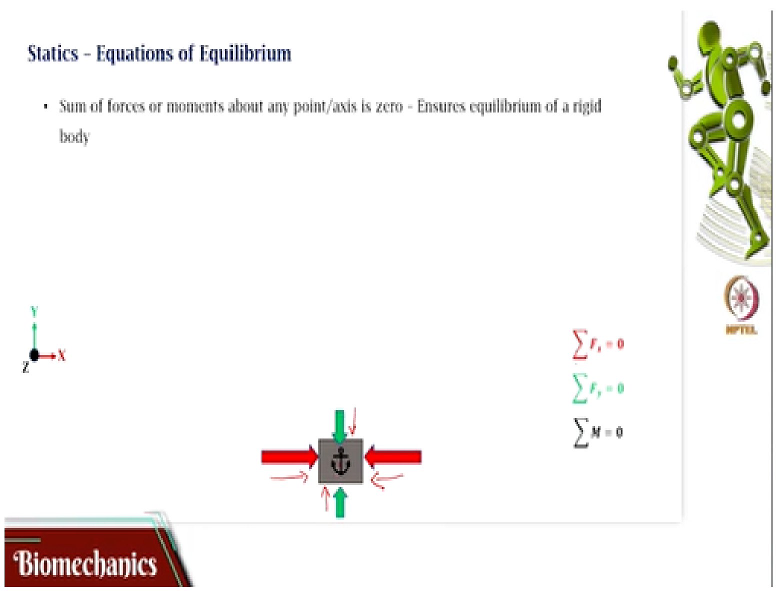

So, to simplify these equations of static equilibrium. In 2D the sum of forces are moments about any point is zero. This will ensure that a rigid body is equilibrium in two dimensions. This is also frequently written as sigma F x = 0, sigma F a = 0 and sigma F m = 0 but what does that mean?

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Note this object can translate in X direction like it was shown now. For example, this object can translate along the positive X direction like it is shown now or it can translate along the negative X direction. So, in other words it can translate along the X direction or it can move up or it can move down. So, this up down movement constitutes one dimension ah or one degree of freedom, the left right X direction of moment constitutes another degree of freedom.

Let us suppose one more moment that it can make is it can rotate about an axis that is perpendicular to the screen. It can rotate about that axis, in other words do that rotation is not perpendicular to that axis are on the plane of the screen. It can rotate about the plane of the screen or within the plane of the screen.

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Now I am restricting if I am restricting the moment of this object in the X direction that means there will be or I can model all the forces as two forces that exactly balance each other like this. Suppose if there was no movement or if there was no acceleration of this object in either direction in the X direction that means that the forces the set of all forces on the X direction is zero. In other words, the sum of forces in the positive X direction and the sum of forces in the negative X direction exactly match each other that is one.

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Now if I want to restrict in that case the object can still move up or down just that it cannot move on left or right. But suppose I want to restrict that moment also then what happens? It can also rotate by the way if I am restricting the movement only in the X direction the object has two degrees of freedom in a vertical direction and the rotation.

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Suppose I am restricting the movement in the y direction what would this mean? This would mean that the set of all forces in the negative y direction and the set of all forces in the positive y direction exactly match each other, exactly balance each other. In this case this object has exactly one degree of freedom which is the rotational degree of freedom. Now I am saying that the entire object is in static equilibrium.

In other words, it is not having an acceleration in either of the directions nor is it having a rotational degree of freedom. Now that means I am anchoring it I am just keeping it completely immobile this would mean that the set of all moments that are applied on the object about the axis that is perpendicular to this plane is zero. This is what gives rise to these famous equations sigma F x = 0 sigma F o = 0 and sigma M = 0. Note that forces for the forces the unit is Newton and for the moments the unit is Newton meter.

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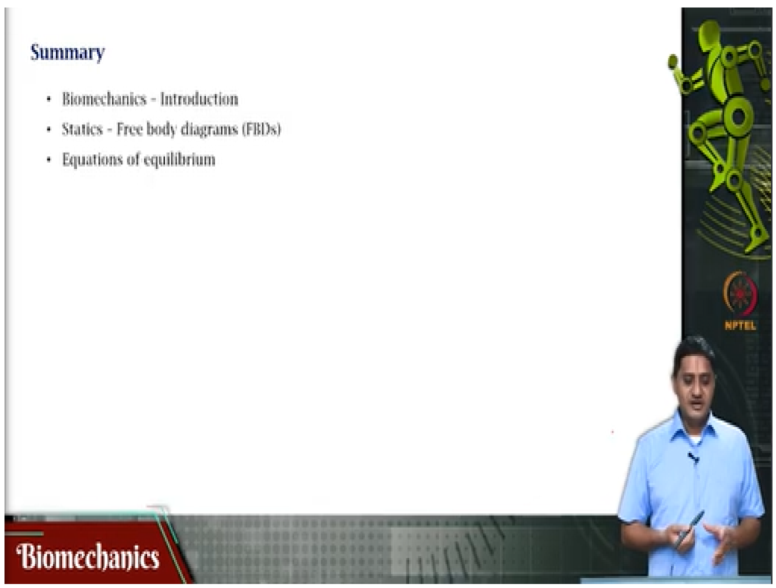

In summary in this class, we have seen an introduction to biomechanics and we also saw an introduction to statics in particular to free body diagrams and we also saw what are equations of static equilibrium we wrote them out. Thank you very much for your attention.