2.5 Equilibrium Analysis in Concurrent Force Systems: Intro

0:01

Hello. In today's video lecture, we will discuss equilibrium analysis in concurrent force systems. In equilibrium analysis, we examine a body that is in equilibrium and use the forces and geometry we know to solve for unknown forces or other unknown values.

For example, consider the forces acting on a barrel sitting in an off-center groove. We may know the gravity force-600 pounds-but want to determine the magnitudes of the two normal forces, F2 and F3.

0:44 Equilibrium Analysis Process

To determine these unknown forces, we use the equilibrium analysis process:

1. Draw a free-body diagram of the body, showing all known and unknown forces.
2. Use the free-body diagram to write the equilibrium equations.
3. Solve the equilibrium equations for the unknowns.

1:13 Free-Body Diagram

When creating a free-body diagram, draw the body being analyzed separately from all background objects. Include all forces acting on the body: normal forces, gravitational forces, friction forces, tension forces, or any other relevant forces. Pay close attention to identifying all forces at play.

Add any angles for the force vectors and key dimensions that will help you solve the problem. In concurrent force systems, angles are particularly important.

1:55 Example

Consider a ladder. First, separate it from the background so only the ladder is drawn. Then add all forces. At each point of contact, include normal forces-one at the wall and one at the floor-each perpendicular to the surface. Add the gravity force acting at the ladder's center.

If the floor is rough, include a friction force parallel to the surface, opposing the direction the ladder would tend to slide. Finally, include the normal force from the man standing on the ladder.

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Add key angles, such as the ladder's angle, and key dimensions: the man is one meter from the top, one meter from the center of gravity, and two meters from the bottom. More information on free-body diagrams can be found in Section 1.4 of the textbook.

3:16 Equilibrium Equations

For a body in equilibrium, the sum of the forces must equal zero. Adding all force vectors-F1, F2, F3, and so on-must result in zero because acceleration is zero.

To solve this vector equation, we break it into component equations. In a 2D problem, we write:

- Sum of forces in the x-direction equals 0.
- Sum of forces in the y-direction equals 0.

Each force is broken into x and y components. All x components must sum to zero, and all y components must sum to zero. For more information on breaking vectors into components, see Appendix Section 1.1.

These component equations give us scalar equations we can solve using algebra. A single vector equation becomes two scalar equations in 2D. In 3D, we would have three equations: sums of forces in x, y, and z.

With two equations in 2D, we can solve for up to two unknowns-for example, the magnitudes of two forces or the magnitude and direction of one force. In 3D, we can solve for up to three unknowns. These unknowns may be magnitudes, angles, or later, in rigid body systems, distances.

6:13 Review

For concurrent force systems, all forces meet at a single point, and we only use force equilibrium equations. In non-concurrent force systems, we must also ensure that the sum of the moments equals zero because there is no angular acceleration. This adds complexity but also provides more equations to solve for more unknowns.

To determine unknown forces:

1. Draw a free-body diagram showing all known and unknown forces, key dimensions, and angles.
2. Use the free-body diagram to write the equilibrium equations, especially the component equations.

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3. Use those equations to solve for unknown force magnitudes or directions.

That concludes today's video lecture. Thank you for watching, and I hope to see you again.