Physics for Physics Teacher 1

Kittipong S. (Ph.D. Physics) | Department of Physics | Faculty of Science and Technology

Mechanical Equilibrium.

Kittipong S. (Ph.D. Physics) | Department of Physics | Faculty of Science and Technology

Swiss Engineering Editorial

Mechanical Equilibrium: The Physics of Balance

Understanding Force, Moment, and Stability.

Impossible? No. Just physics. When forces and moments cancel out, even the precarious becomes stable.

Equilibrium is the Absence of Acceleration.

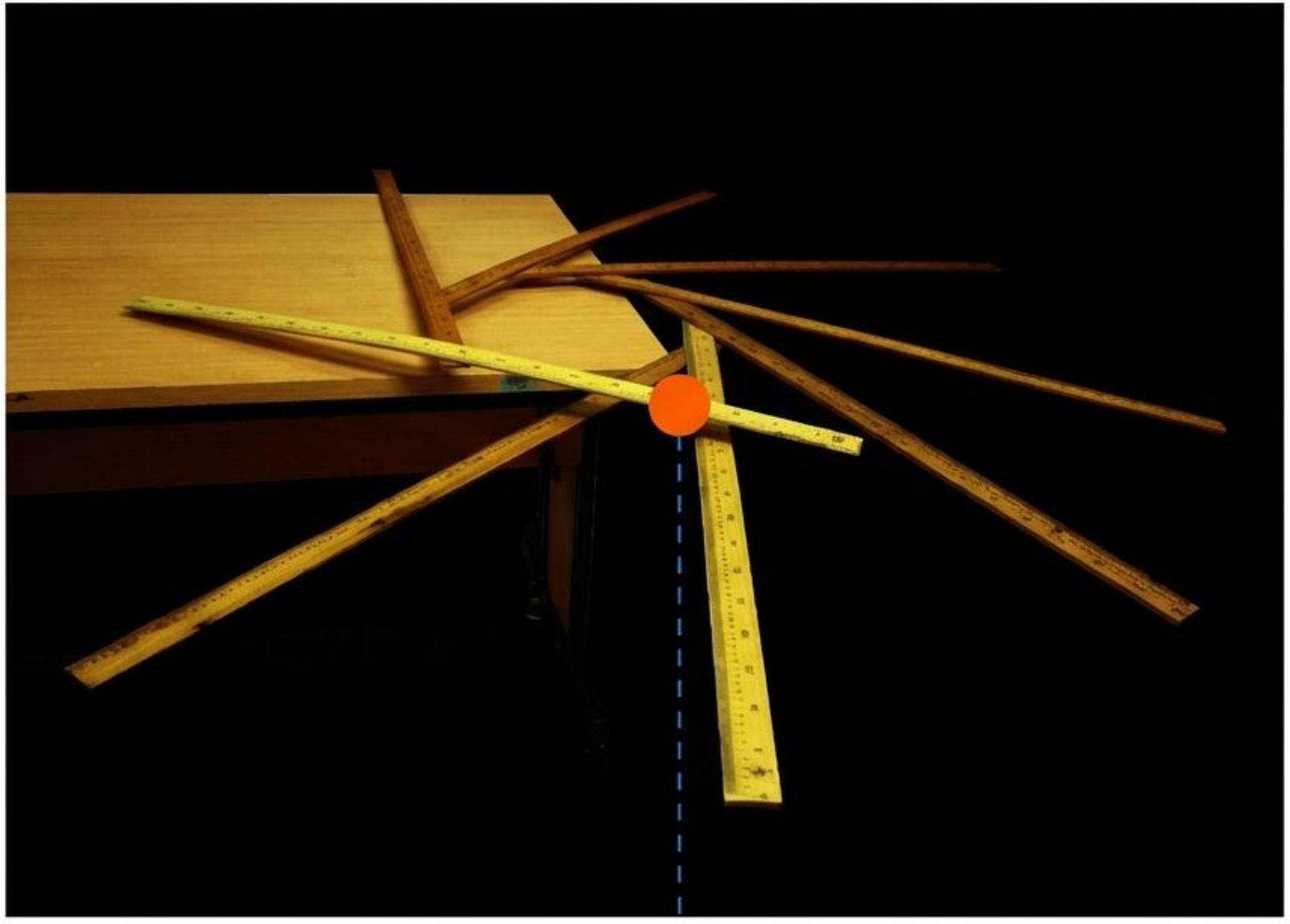
Static Equilibrium (v = 0, a = 0)

Dynamic Equilibrium (v = constant, a = 0)

$$\Sigma F = 0$$

An object in equilibrium maintains its state of motion.
The net influence upon it—the **vector sum of all forces**—is **zero.**

The Anchor Point: Center of Mass (CM)



Definition: The point where the object's entire mass effectively concentrates.

The Rule: In a uniform gravitational field, Center of Mass (CM) = Center of Gravity (CG).

Insight: Gravity acts through this point. If you support an object here, it balances in any orientation.

Condition #1: Translational Equilibrium

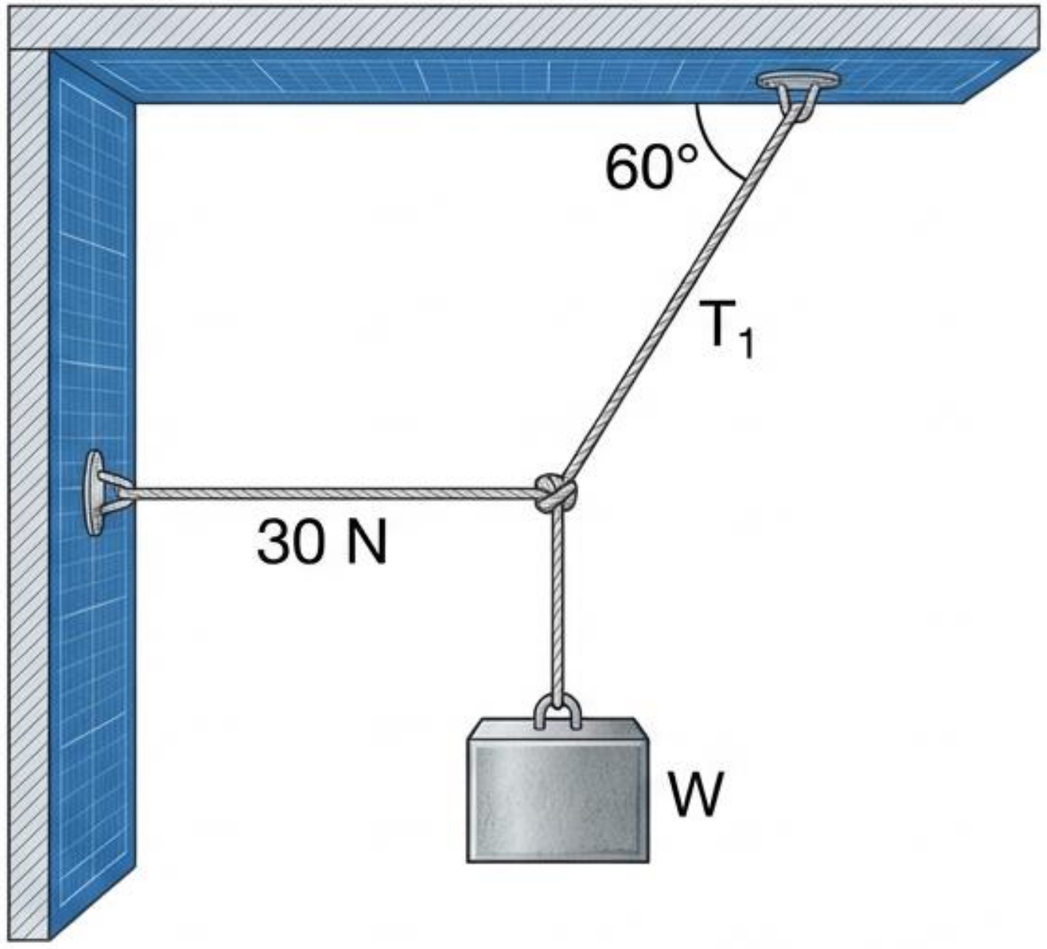
The object must not accelerate linearly.

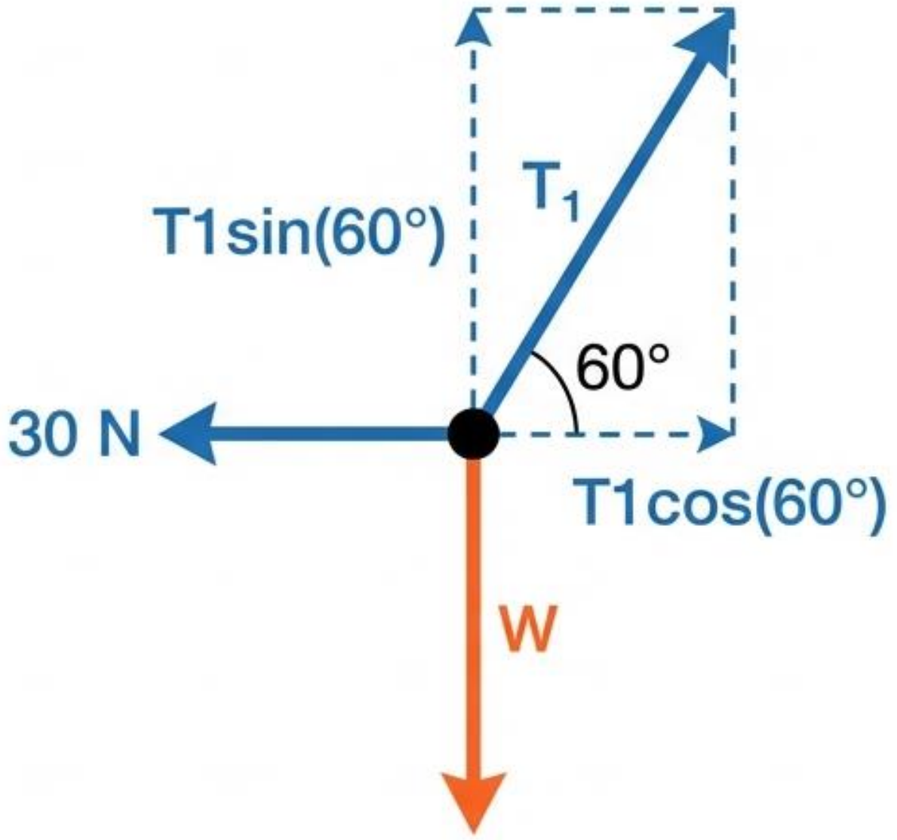
$$\sum F_x = 0 \quad \text{(Forces Left = Forces Right)}$$

$$\sum F_y = 0 \quad \text{(Forces Up = Forces Down)}$$

Key Insight: If these forces don't cancel, the object slides.

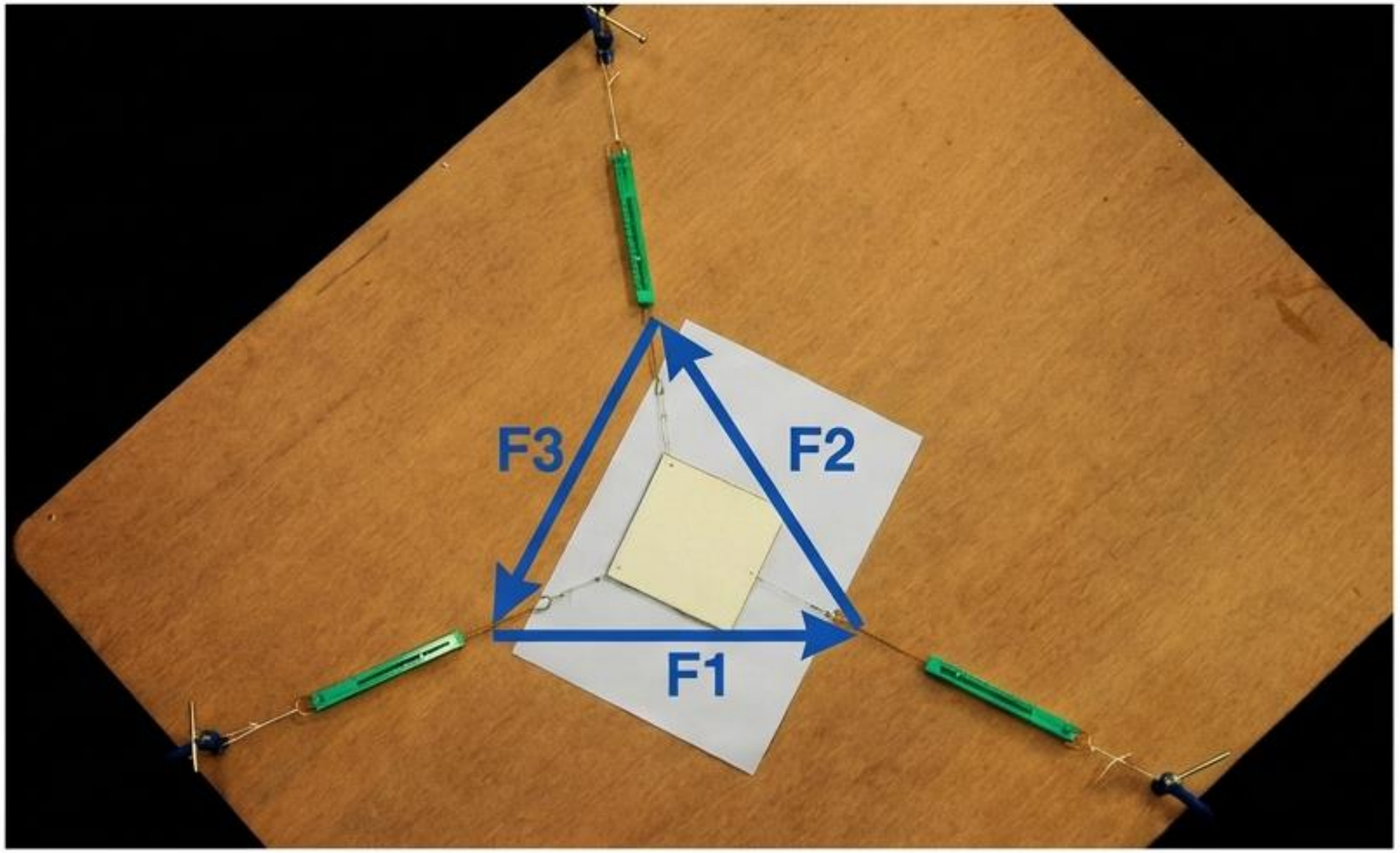
Visualizing the Invisible: The Free Body Diagram





$$T1\cos(60°) + T2\cos(30°) = W$$

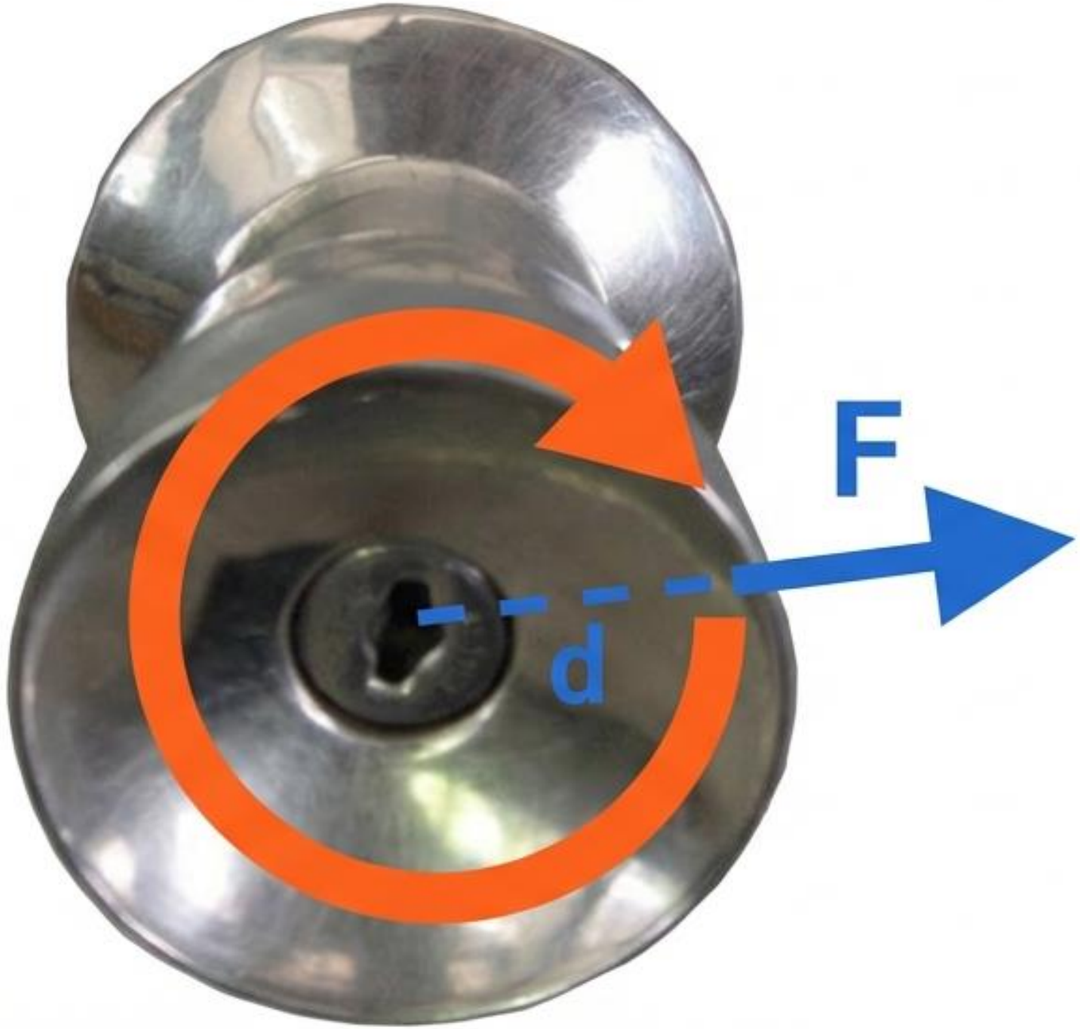
The Rule of Three: Lami's Theorem & Triangle Law



- **The Triangle Law:** If 3 non-parallel forces balance, they must meet at a single point and form a closed vector triangle.
- **The Check:** If the triangle stays open, the object moves.

Condition #2: Rotational Equilibrium

The object must not start spinning.

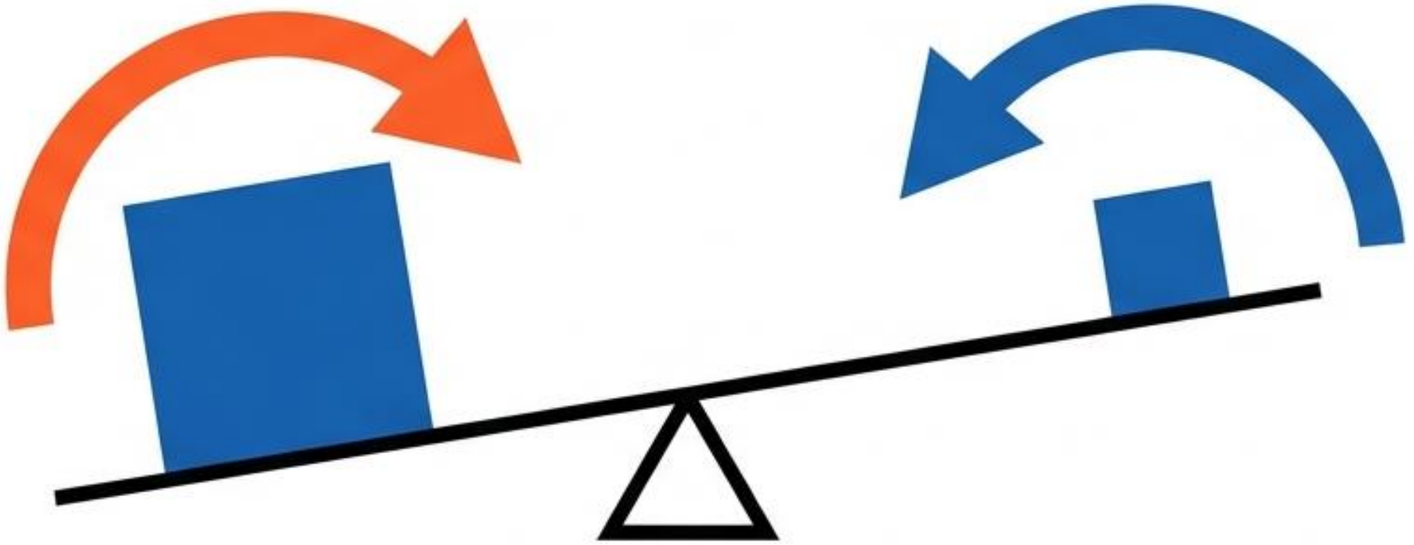


Moment (Torque) = Force × Perpendicular Distance

($M = F \cdot d$)

- **Key Insight: A force applied directly at the pivot point creates** zero moment because d=0.

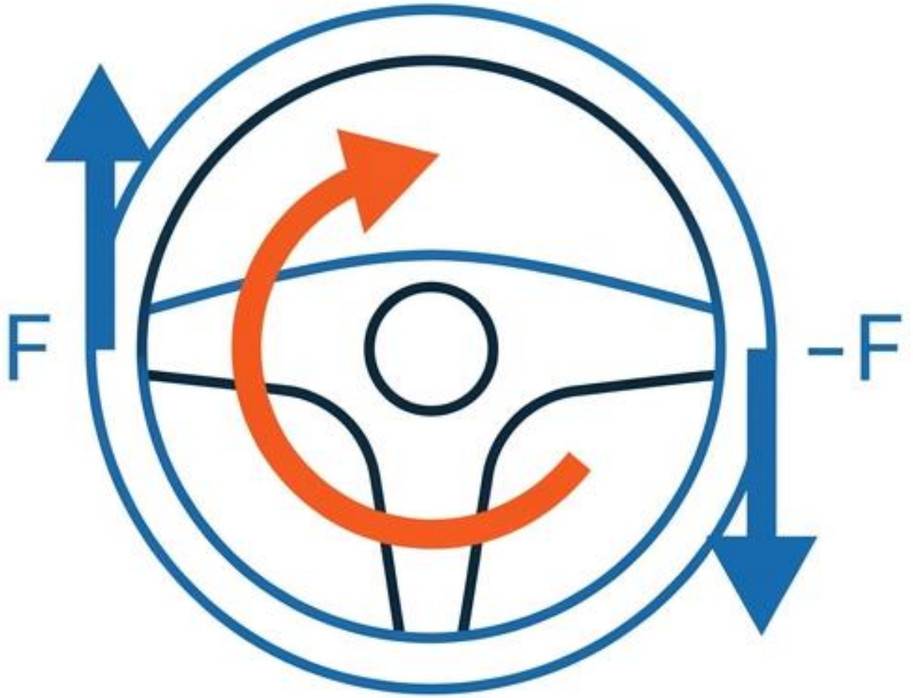
Balancing the Turns



$$\sum M(\text{clockwise}) = \sum M(\text{counter-clockwise})$$

Strategy: You can choose *any* point as your pivot.
Pro Tip: Pick the pivot where an unknown force acts to eliminate it from the equation.

The Couple: Pure Rotation

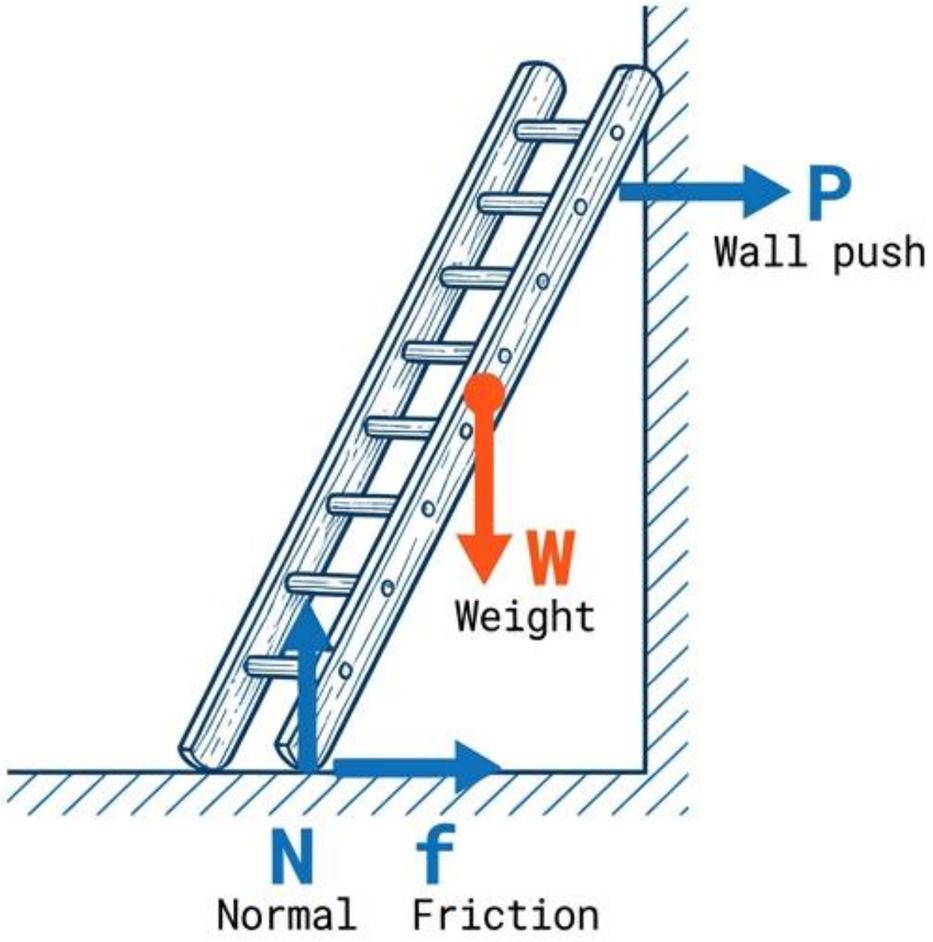


Definition: Two equal, opposite, parallel forces.

The Trap: $\sum F = 0$ (Translational equilibrium is satisfied!) but $\sum M \neq 0$ **(It spins!)**.

Solution: To balance a couple, you cannot use a single force. You must apply an opposing couple.

The Complete Equilibrium Checklist



1. **Vertical:**
   Floor push (**N**) = Weight (**W**)

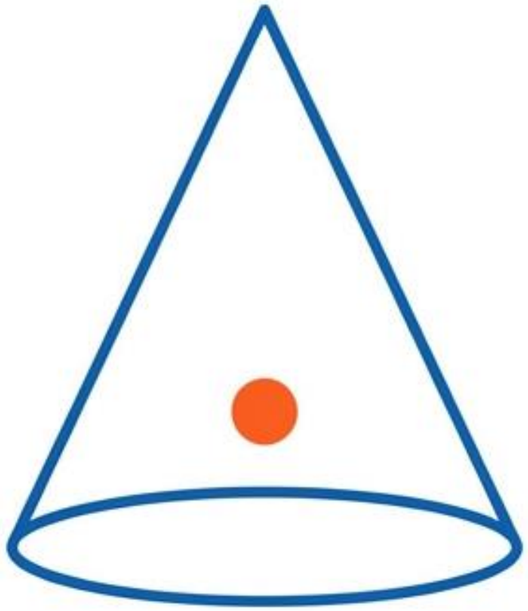
2. **Horizontal:**
   Wall push (**P**) = Friction (**f**)

3. **Rotational:** The Moment from the wall push must equal the Moment from the ladder's weight.

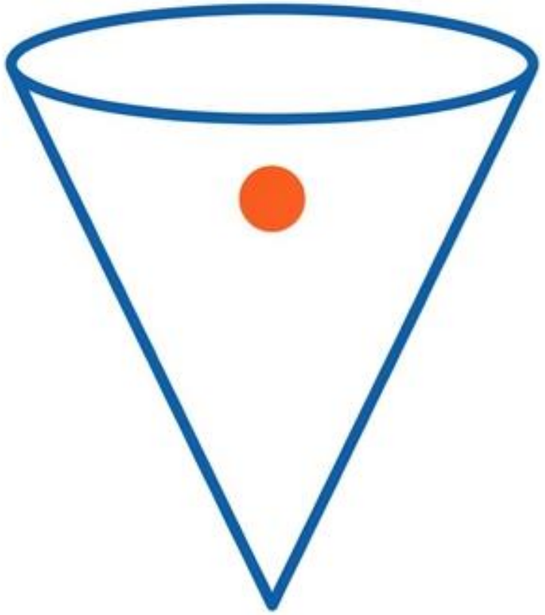
Solvable only when all three conditions are met simultaneously.

Swiss Engineering Editorial

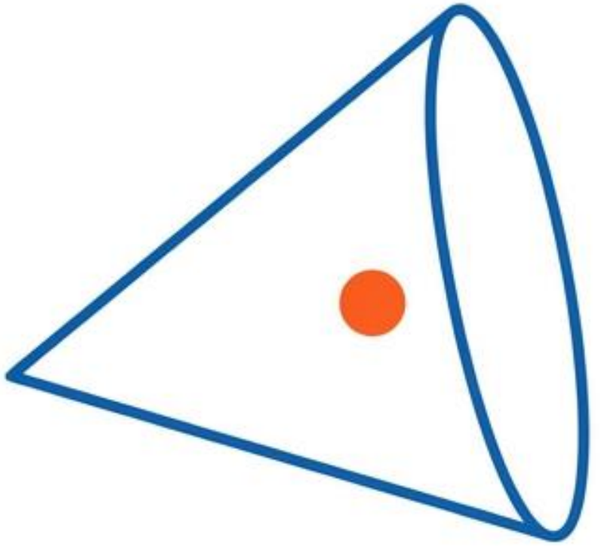
Stability: The Art of Staying Balanced



Stable: Returns to position if disturbed (CG rises).



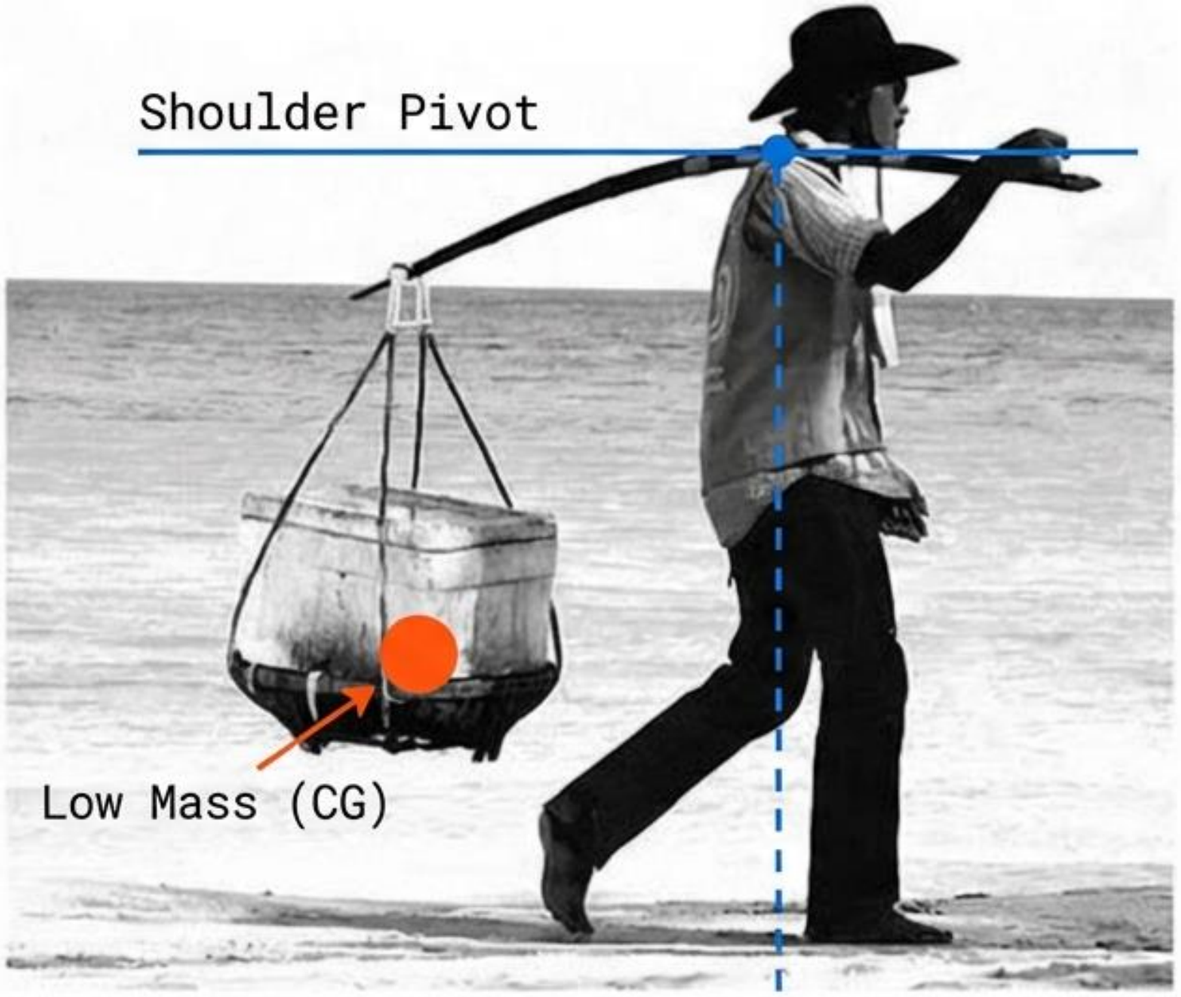
Unstable: Falls further if disturbed (CG falls).



Neutral: Stays in new position (CG level).

Factors of Stability

Swiss Engineering Editorial

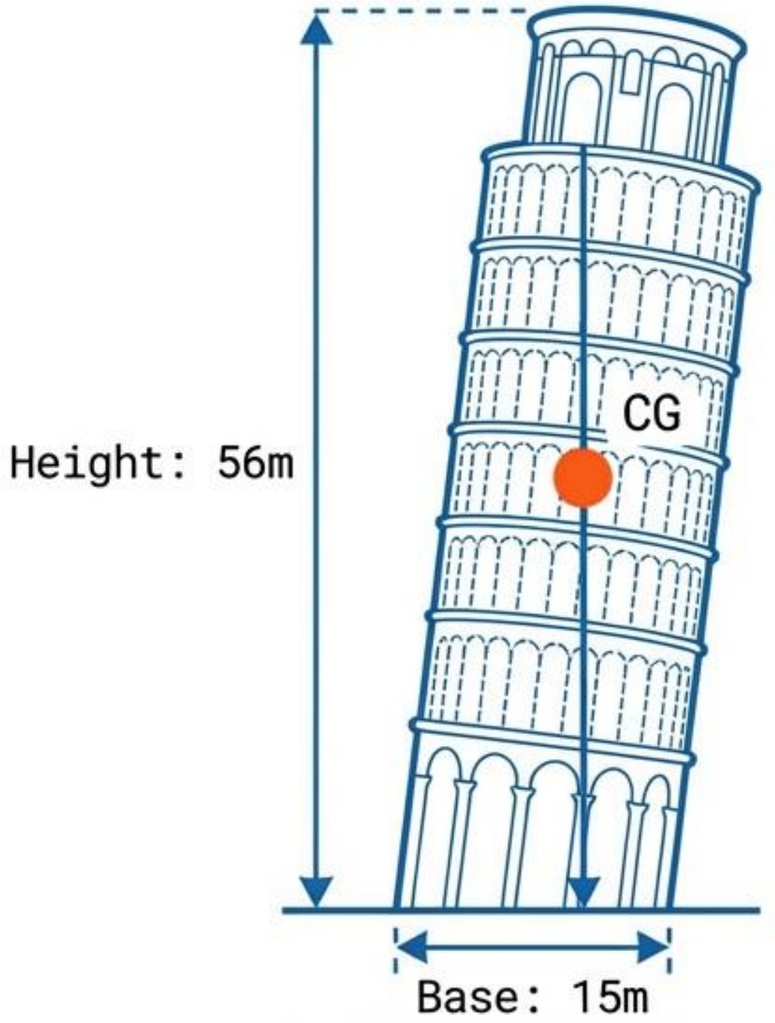


1. Low Center of Gravity:
The baskets hang low, lowering the system's CG below the shoulder pivot.

2. Wide Base of Support:
Stability increases as the vertical line of gravity moves further from the tipping edge.

Swiss Engineering Editorial

Case Study: The Leaning Tower



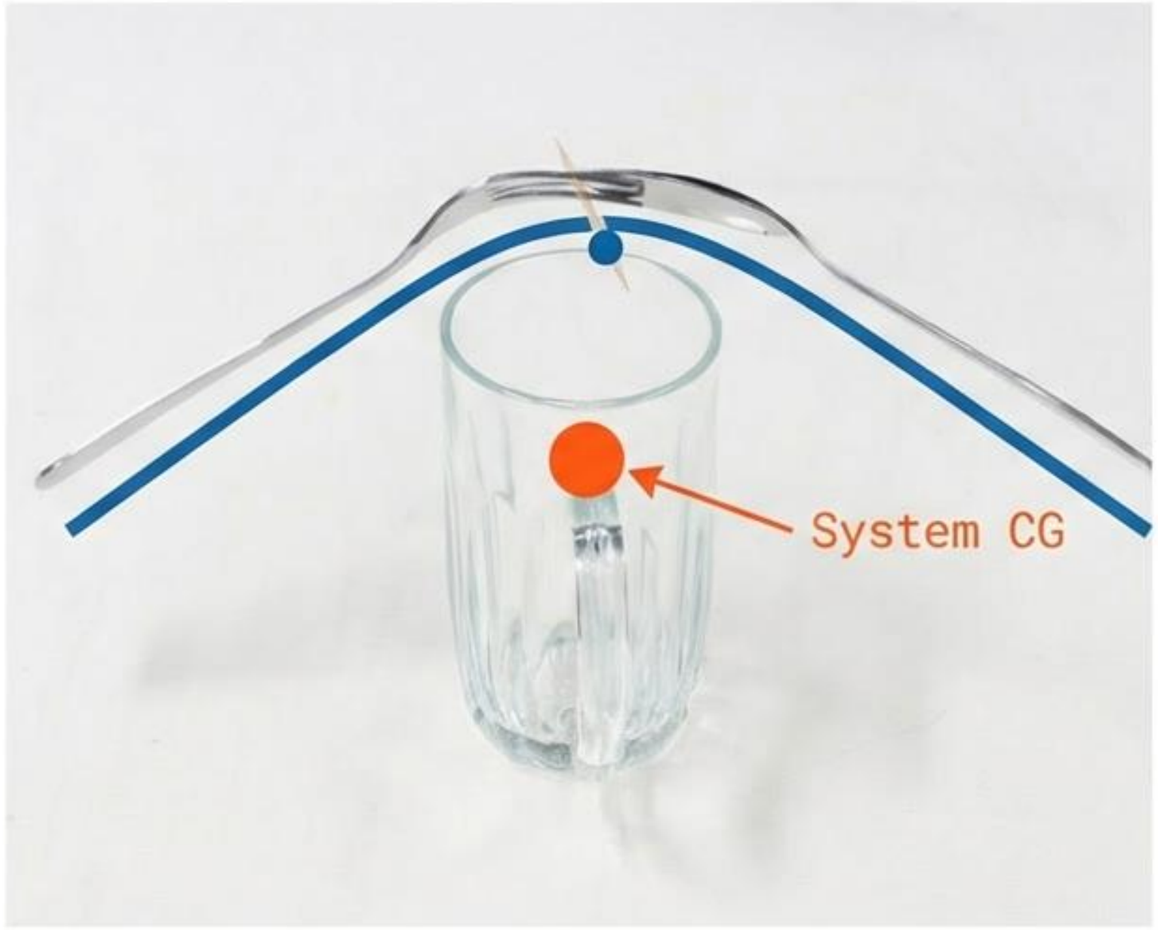
Current Lean: ≈ 3.9m deviation.

Status: Stable (Line of Gravity falls inside the base).

Tipping Point: If the lean exceeds ≈ 7.5m, the line crosses the edge. Collapse is inevitable.

Swiss Engineering Editorial

Explained: The Impossible Balance



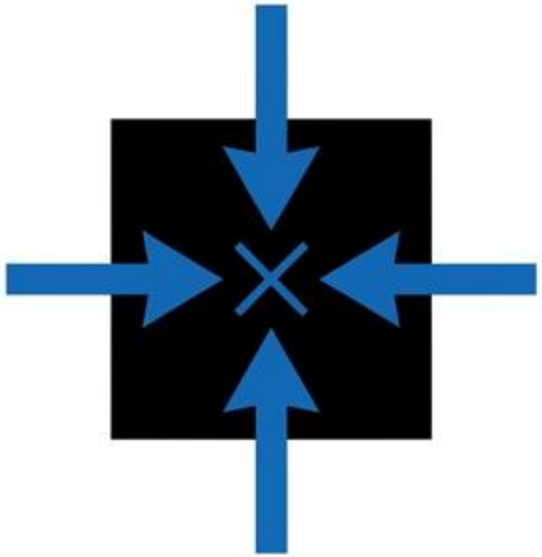
The Reveal: The heavy handles curve downward.

Analysis: The System Center of Gravity is in the empty air below the pivot point.

Conclusion: It acts like a hanging pendulum (Stable Equilibrium).

Swiss Engineering Editorial

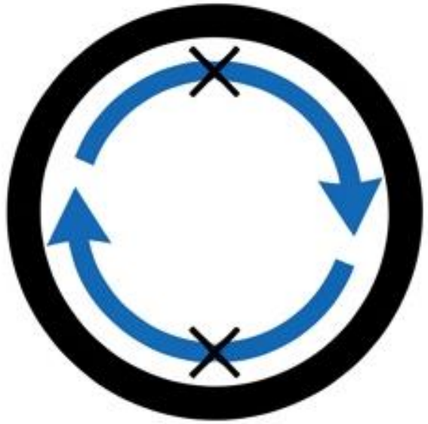
Summary: The Physics of Balance



Translation:

$\sum F_x = 0, \sum F_y = 0$

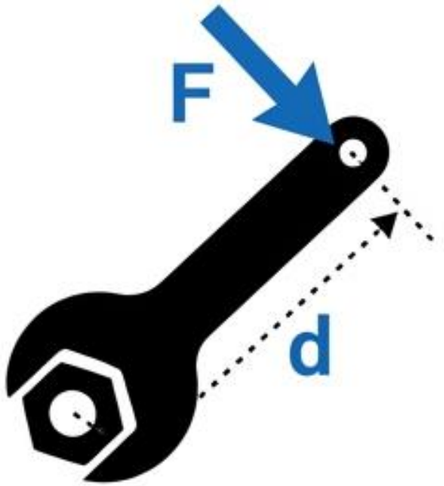
(Stop Sliding)



Rotation:

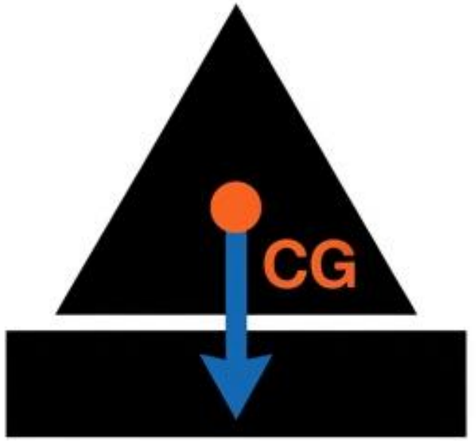
$\sum M_{cw} = \sum M_{ccw}$

(Stop Spinning)



Moment:

$M = F \cdot d$



Stability:

Keep Line of Gravity inside Base

Equilibrium isn't passivity. It is the perfect cancellation of opposing forces.