WEEK 9

Physics of Engineer

Chapter 8: Equilibrium

Kittipong Siengsanoh (Ph.D.Physics)

Department of Physics

Faculty of Science and Technology

Outline

- ❑Equilibrium
- ❑What is Equilibrium
- ❑Consequences of Equilibrium
- ❑Identifying Equilibrium
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Outline

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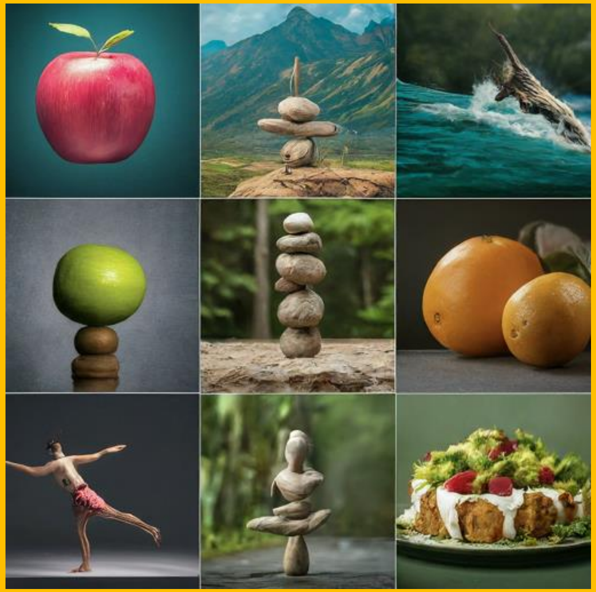
Equilibrium: Understanding the Balance of Forces



What is Equilibrium?

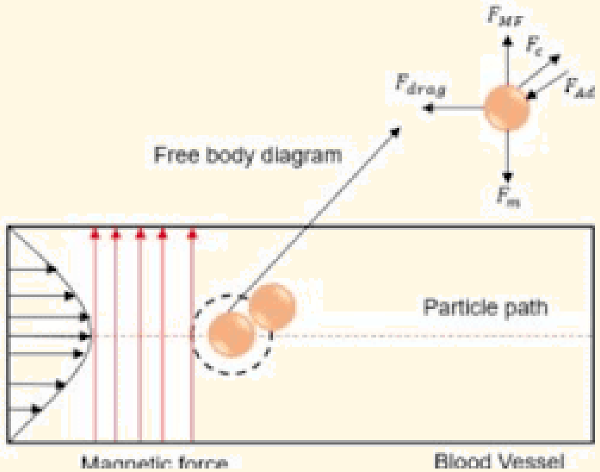
- **Definition:** Equilibrium refers to the state of a particle where the **net force** acting on it is **zero**.

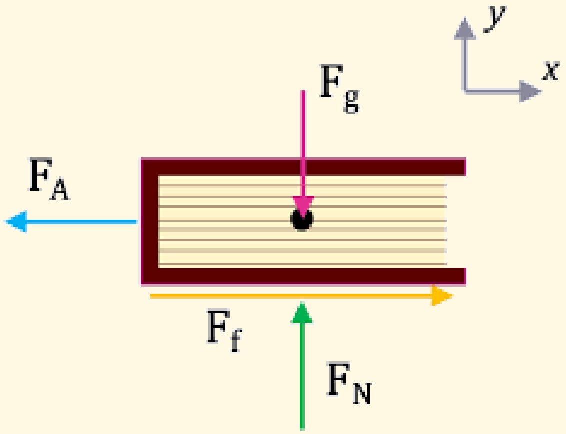
- **Parameters:**
    - **Net Force:** The vector sum of all forces acting on a particle.

- **Symbolic Representation:**

$$\Sigma F = 0$$

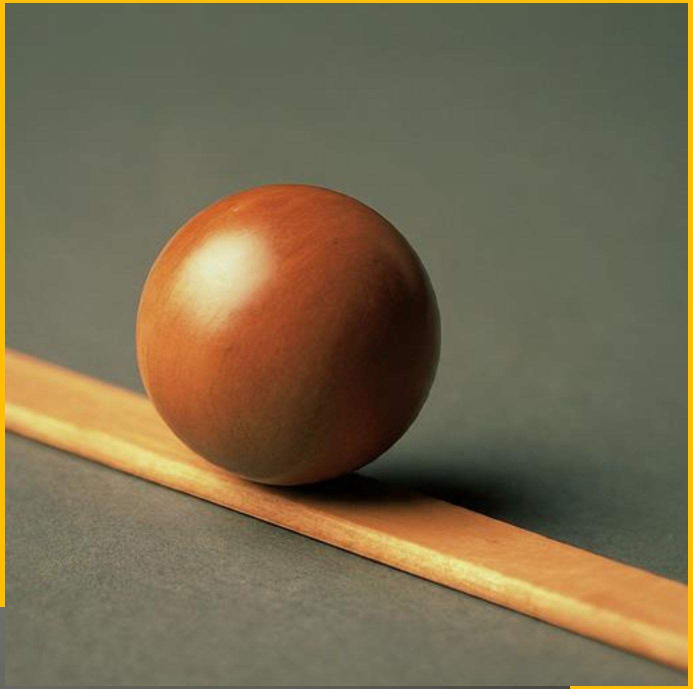
(where Σ represents the sum and F represents the force)

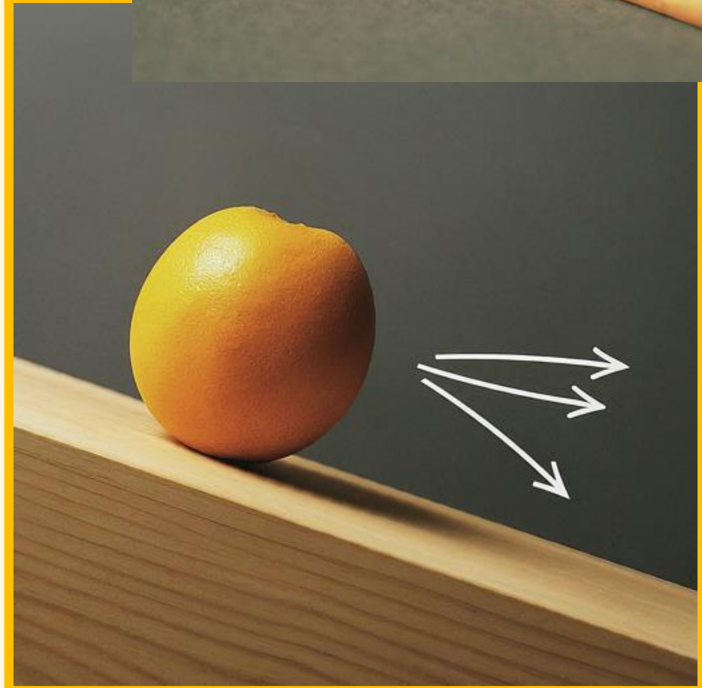




Consequences of Equilibrium

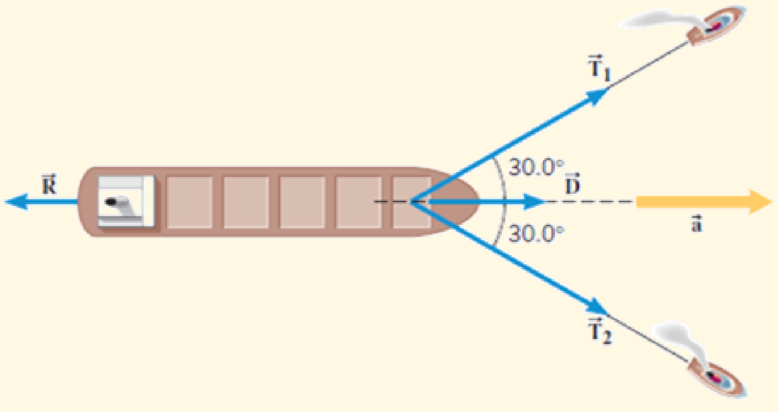
- Motion:
  - **Zero net force:** A particle in equilibrium will either be at rest or move with **constant velocity**.
  - **Non-zero net force:** A particle with a non-zero net force will experience **acceleration** in the direction of the net force.



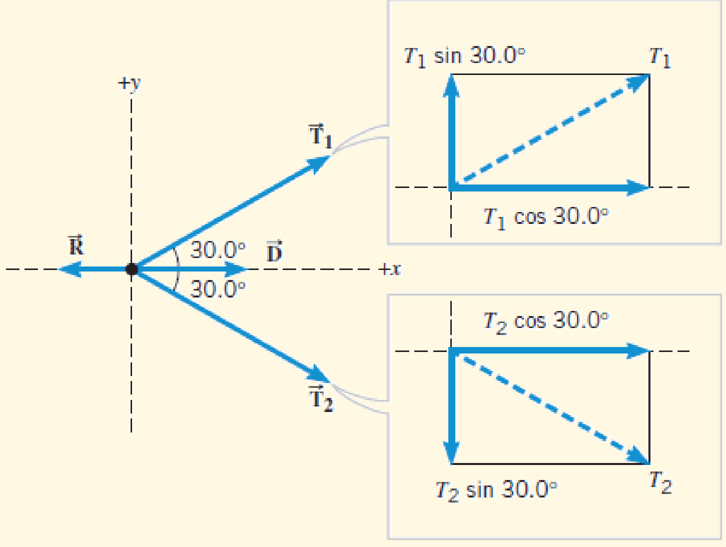


Identifying Equilibrium

- Steps:
  1. Identify all forces: Draw a free-body diagram showing all forces acting on the particle.
  2. Resolve forces: Break down each force into its components along horizontal and vertical axes (if applicable).
  3. Apply equilibrium conditions: Set the sum of forces in each direction (horizontal and vertical) equal to zero.
  4. Solve for unknowns: Use mathematical equations to solve for unknown forces or other parameters.



(a)

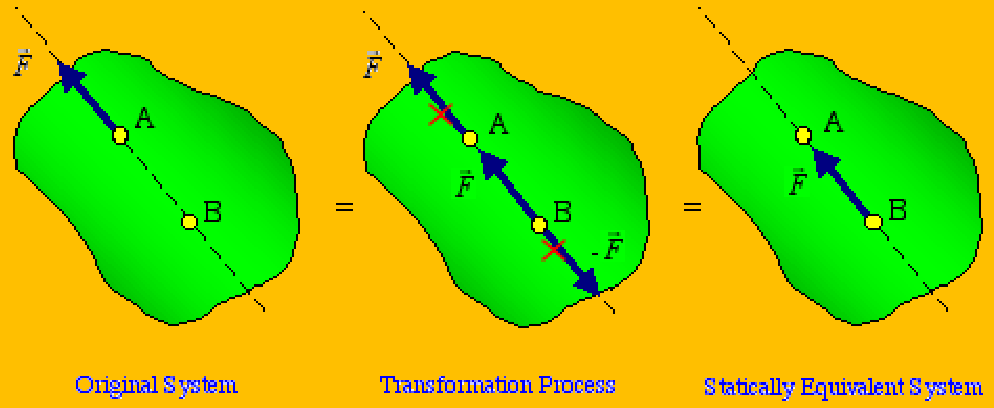


(b) Free-body diagram for the tanker

Equivalent Systems of Forces

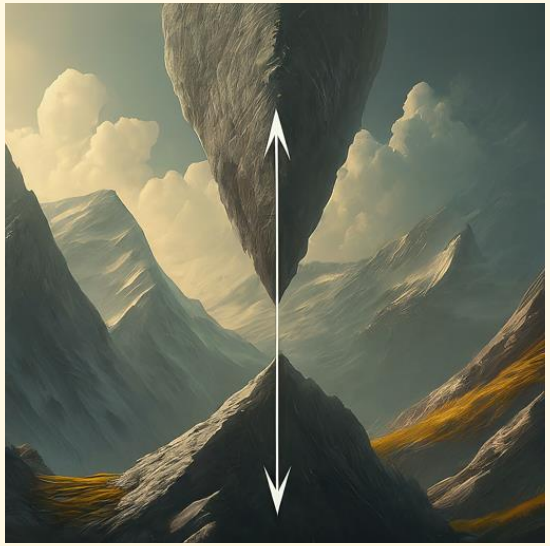
- **Definition**: Two systems of forces are considered **equivalent** if they produce the same effect on a rigid body, regardless of their individual point of application.

- **Parameters**:
    - **Line of Action**: The line along which a force acts.
    - **Moment**: The tendency of a force to cause rotation about a point.



Conditions for Equivalent Systems

- Two conditions for equivalent systems:
  - **Equal vector sum:** The sum of forces in each system must be equal in both magnitude and direction. ($\Sigma F_1 = \Sigma F_2$)
  - **Equal moments:** The sum of the moments of the forces about any point must be equal in both systems. ($\Sigma M_1 = \Sigma M_2$)



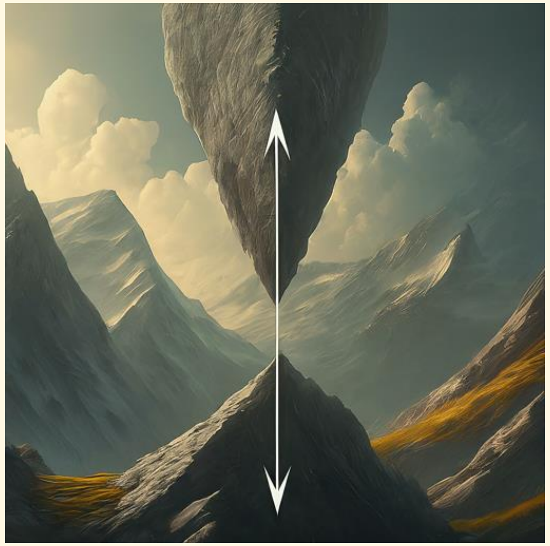
Conditions for Equivalent Systems

- Mathematical Equations:

$$\Sigma F_1 = \Sigma F_2 \text{ (Sum of forces)}$$

$$\Sigma M_1 \tau_1 = \Sigma M_2 \tau_2$$

(Sum of moments, where τ represents the distance from the point of rotation to the line of action of the force)



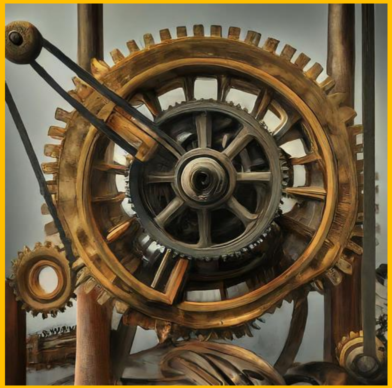
Applications of Equilibrium and Equivalent Systems

- **Engineering:**
    - **Structural analysis:** Equilibrium and equivalent systems are crucial for analyzing forces acting on structures like bridges, buildings, and machines to ensure their stability and prevent collapse. Engineers use these concepts to design safe and efficient structures.

Applications of Equilibrium and Equivalent Systems

- Machines:
  - **Lever systems:** Levers work based on the principle of equilibrium, where the moments of forces acting on different ends balance each other, allowing for efficient lifting or transmitting forces.
  - **Gears and pulleys:** These mechanical components rely on equivalent systems of forces to transmit and change the direction and magnitude of applied forces, enabling various functionalities in machines.



Applications of Equilibrium and Equivalent Systems

- Everyday life:
    - **Stability of objects:** Understanding equilibrium helps us predict the stability of everyday objects. For example, a leaning tower remains standing as long as the net moment of forces keeps it from tipping over.
    - **Balancing objects:** Balancing objects on a seesaw or a fulcrum is a practical application of equilibrium, where opposing forces cancel each other out, creating a state of rest.

Types of Equilibrium

- Types:
  - **Static equilibrium:** A particle remains at rest.
  - **Dynamic equilibrium:** A particle moves with constant velocity.
  - **Unstable equilibrium:** A slight disturbance can cause the particle to move away from its original position.
  - **Stable equilibrium:** A small disturbance will cause the particle to return to its original position.
  - **Neutral equilibrium:** A small disturbance will not significantly affect the particle's position.





Conclusion

- **Recap the key takeaways:** Briefly summarize the fundamental concepts covered in the presentation, emphasizing the importance of equilibrium and equivalent systems of forces.
- **Highlight the significance:** Discuss the widespread applications of these concepts in various fields, including engineering, mechanics, and even everyday life.
- **Emphasize the value of understanding:** Explain how understanding equilibrium empowers individuals to analyze forces, predict object behavior, and design stable and functional structures and machines.
- **Encourage further exploration:** Briefly mention the vastness of the topic and encourage students to delve deeper by suggesting relevant resources, books, or online courses.

Resources and References

- Recommended textbooks:
    - **Engineering Mechanics: Statics and Dynamics** by Ferdinand P. Beer and E. Russell Johnston Jr. (14th Edition). This comprehensive textbook offers a clear and detailed explanation of the principles of equilibrium, forces, and motion, with numerous examples and practice problems.
    - **Introduction to Classical Mechanics** by David Morin (2008). This advanced text delves deeper into the theory of mechanics, offering a rigorous mathematical treatment of equilibrium and its applications in various systems.
    - **Fundamentals of Physics I** by David Halliday, Robert Resnick, and Jearl Walker (11th Edition). This introductory physics textbook provides a solid foundation in classical mechanics, including chapters on forces, motion, and equilibrium.
- Online resources:
    - https://www.khanacademy.org/science/mechanics-essentials - This website offers interactive learning modules and practice problems on various physics topics, including equilibrium.
    - https://ocw.mit.edu/courses/physics/ - This website provides lecture notes and materials from an MIT course on classical mechanics, covering the principles of equilibrium and forces.

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