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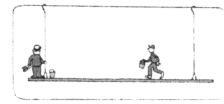
Notes – Mechanical Equilibrium

Key 13-14



I. Equilibrium

A. What is "entropy"?

1. Nature follows rules. One rule that governs much of what happens in nature is the law of entropy. This law says that things that are unstable will tend towards a state of stability where they will remain unless disturbed.
2. How do you recognize that a system is unstable? If the system is organized / ordered then it is considered unstable, and thus will naturally tend towards disorganized / disordered unless energy is put into the system to maintain order.

Example 1: Examples of unstable systems heading towards stability:

vert. meterstick → fall
mountain → plain
card house → pile
closet → pile
me → dirt

B. How does the idea of entropy apply to physics?

1. For physical objects, like a meter stick or ball, we recognize them as being unstable when we see them unbalanced. For physical objects, stability can be achieved by becoming balanced.
2. When objects are in balance, we say they are in a state of mechanical equilibrium and there they will remain unless $F_{net} \neq 0$ is applied to them. not just F, Fnet.

Apply a F to bowling ball doesn't take it out of mech eq. Fnet does.

II. Mechanical Equilibrium

A. How do you know if an object is in mechanical equilibrium?

1. If the object/system is experiencing no Δ (change) in motion than it **is** in mechanical equilibrium.
2. If an object is experiencing a Δ motion (speeding up, slowing down, or changing direction), than it is **not** in mechanical equilibrium.

Example 2: Examples of objects/systems in mech. eq.: computer, acrobats, bowling ball?

B. What do you know about a system that is in mechanical equilibrium?

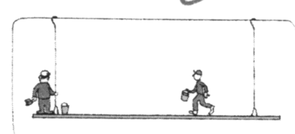
1. Remember, when an object is in mechanical equilibrium, all the forces acting on it are balanced. This means any up forces are balanced out by down forces; any left are balanced out by right.
2. This is known as the equilibrium rule and can be expressed as follows:

Equation: sum → $\Sigma F = 0$ so... $F_{net} = 0$

C. There are two types of mechanical equilibrium:

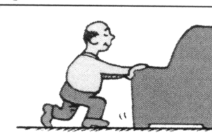
a. Static Equilibrium

- i. Static means not moving.
- ii. If an object is not moving, then the object is experiencing no Δ motion.
- iii. If an object is experiencing no change in motion, than it is in mech. eq.
- iv. The mechanical equilibrium that exists for still objects is called static. eq.
- v. All static (still) objects are in mechanical (static) equilibrium.
- vi. If an object is in mechanical equilibrium, then $\Sigma F = 0$.
- vii. So, for static (still) objects, we can say $F_{net} = 0$.



b. Dynamic Equilibrium

- i. Dynamic means moving.
- ii. If an object is moving, then the object might be be experiencing no change in motion
- iii. When an objects is traveling at a constant speed and going in a straight line, it is experiencing no change in motion. This type of non-changing motion is called a constant velocity.
- iv. If an object is going a constant velocity, then it is in mech. eq.
- v. The mechanical equilibrium that can exist for moving objects is called dynamic equilibrium.
- vi. Some dynamic (moving) objects are in mechanical equilibrium.
- vii. If an object is in mechanical equilibrium, then $\Sigma F = 0$.
- viii. Then, for dynamic (moving) objects going at a constant velocity, we can say $F_{net} = 0$.



Example 3: Can an object with only once force working on it be in mechanical equilibrium? → No!

III. Mechanical Equilibrium Calculations

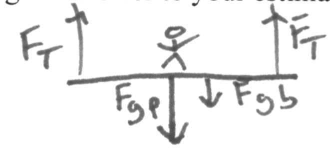
A. Why is it Useful to Recognize a System is in Mechanical Equilibrium?

1. Knowing that an object, or group of interrelated objects (called a system), is in mech. eq. can help us calculate information we don't know (unknowns) from information that we do know (knowns).

B. Steps to Approaching Problems Involving Calculations

1. **Step 1: Read and Understand**
   - Read the problem & underline the important stuff. Name the variables & unknown(s) and list them. Draw a labeled picture/free body diagram and check to see that all of the knowns have the correct sign convention.
2. **Step 2: Plan and Solve**
   - Find/create an equation that solves for the unknown(s). Solve equation for the variable you are looking for.
3. **Step 3: Look Back and Check**
   - Determine if your answer is reasonable by estimating, then comparing the answer to your estimation.

Example 4: A painter stands on the middle of a board that is suspended at the ends by two vertical ropes. The painter and the board are in mechanical equilibrium. The tension in each rope is 350 N, & the painter's weight is 550 N. What is the weight of the board?

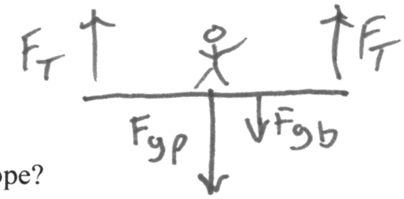


Equation	Variables & Values	Solve & Simplify
$F_{net} = 0$ $F_{net} = 2F_T + F_{gp} + F_{gb}$ $0 = 2F_T + F_{gp} + F_{gb}$ $F_{gb} = -2F_T - F_{gp}$	$F_{gb} = ?$ $F_T = 350N$ $F_{gp} = -550N$	$= -2(350N) - (-550N)$ $= -700N + 550N$ $= \boxed{-150N}$

Example 5: Three vertical ropes (two on ends, one in middle) hold up a board that weighs 180 N. What is the tension in each rope?

$F_{net} = 0$ $F_{net} = 3F_T + F_{gb}$ $0 = 3F_T + F_{gb}$ $F_T = \frac{-F_{gb}}{3}$	$F_T = ?$ $F_{gb} = -180N$	$= \frac{-(-180N)}{3}$ $= \boxed{60.N}$

Example 6: Suppose a painter weighing 700.N stands on the middle of a board suspended by two vertical ropes positioned at the ends. If the weight of the board is 180.N, what is the tension in each rope?



$F_{net} = 0$ $F_{net} = 2F_T + F_{gp} + F_{gb}$ $F_T = \frac{-F_{gp} - F_{gb}}{2}$	$F_T = ?$ $F_{gp} = -700.N$ $F_{gb} = -180.N$	$= \frac{-(-700.N) - (-180.N)}{2}$ $= \boxed{440.N}$