Royal Robotics
Lesson Plan – Mechanics: Structure
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Definition: A machine is a series of parts designed to apply a force. Those parts usually need a framework to properly space and support them. Structural mechanics analyzes how that framework supports or resists forces.

Concepts & Principles:

In structural engineering an applied force (a push or a pull) on a structure is called a **load**. Loads come in two types:

> **Dead or Permanent** loads do not change over time. They are made by static forces such as the pull of gravity acting on the weight of the materials used. (poster)
>
> **Live or Probabilistic** loads are temporary or changing. They are made by dynamic forces such as cars crossing a bridge, or the movement of a swing arm. (posters)

Loads create **stress** on a structure. Stress comes in two forms: (hand out 2 tootsie rolls)

> (pull on roll 1) **Tension** is a pulling stress that lengthens or stretches the material. If the tension is more than it can withstand the object will snap apart.
>
> (push on roll 2) **Compression** is a pushing stress that shortens or compacts the material. If compression is more than it can withstand the object buckles or folds.

When a load is applied at a distance from a pivot or fixed point it creates **Torque** (think of a swingset, as swing moves poles bend and sway). How much torque force depends on the distance from the pivot and the size of the load.

There are two methods for handling unwanted stress or torque on a structure:

> **Dissipation** is where you spread the stress over a larger area or mass so that no one piece is overloaded, which keeps the stress under the level the material can withstand.
>
> **Transfer** is moving the stress from a weak area to a stronger one that can handle the load or use it. This usually requires connecting the weak area to a stronger area, like strings on the corners of tents that go out to a stake in the ground.

Another science principle that applies to structures is **Center of mass** This is the point where mass is balanced equally in opposite directions. This is often NOT the physical center of the height, width or length of an object. It is a function of length and weight. For example, you can lower the center of mass in two objects of the same height, by putting heavier parts nearer the bottom. Putting weight in a specific location to change center of mass is called a **Counterweight.** Keeping the center of mass low is important when the object moves as the higher the center of mass the more unstable or tippy the object.

> Demo1: volunteer carries one block tower wide at base and one tower wide at top, which is easier to balance?

Applications:

Materials:

When making a structure you need to consider the properties of the materials used, such as mass, density, tensile strength, flexibility, etc. In Robotics, there is the constant trade-off between strength and weight.

Different materials will be used for different purposes. The most commonly used material is aluminum (show examples) which gives a high strength to weight ratio. Since aluminum is a relatively soft material, steel parts may be used (show example) where greater strength is required. Where low weight is more important than strength, plastic may be used (show example).

Joints:

One consideration in building is always the areas where parts join. If a joint is weak, when a load or torque is placed on that point it is more likely to break. One way to improve joins is by limiting possible motion by increasing points of contact. For example: if an object only has one contact point (place tube upright), it can be pushed in nearly any direction. If an object has two points of contact (place narrow box) then it can now be easily pushed in only two directions. Add a third direction making three points of contact (place wide box) then it is hard to push in any direction. One way joints can be strengthened is to add bracing or brackets in two directions opposite the object's direction, pinning it along 3 lines of motion (see poster)

Supplies: posters, tootsie rolls, blocks, tube/boxes, materials examples, bracket examples