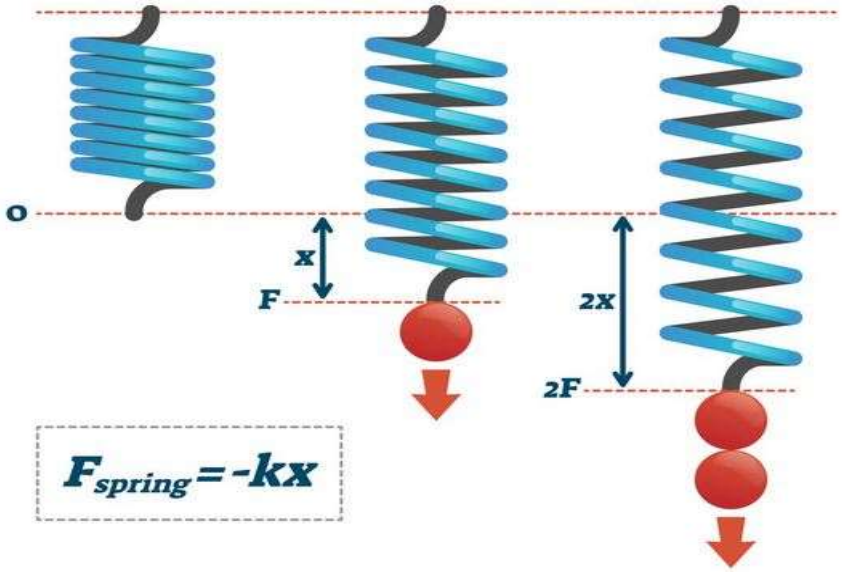

Physics of Skeletons

Fifth Lecture (5)

First semester / First year

By

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Physics of Skeletons

Bones of the Human Body:

Bone: is a living tissue that has a blood supply as well as nerves with a special kind of cells distributed through the bone tissue; these cells are called ***"Osteocytes".*** The Osteocytes cells maintain the bones in a healthy condition. Because of the importance of bones to the proper functioning of the body, a number of medical specialists are concerned with bone problems.

Bone is of interest to medical physics; perhaps this organ system of the body appeals most to physical scientists because of engineering-type problems dealing with static and dynamic leading forces that occur during standing, walking, running, lifting, and so forth.

Bone Composition:

Bones consist of two different materials plus water, which are:

- **Collagen:** it is the major organic fraction of the solid bone. It is quite flexible; it has a fair amount of tensile strength so that it can bend easily if it's compressed. It forms about 40% of the weight of the solid bone and 60% of its volume.
- **Bone Minerals:** are the inorganic parts of the solid bone. It is made up of calcium hydroxyapatite. It is very fragile and forms about %60 of the weight of the bone and 40% of its volume. Because of the small size of the crystals, bone minerals have a very large surface area. Around each crystal is a layer of water containing a solution of many chemicals needed by the body.

Bone = Collagen + Bone Mineral + Water

Functions of Bone:

The functions of bones can be summarized as follows:

1. **Supporting:** the system of bones and muscles supports the body. The muscles are attached to the bones through tendons and ligaments.
2. **Locomotion:** E.g., one joint that permits the movement of one bone with respect to another.
3. **Protection:** protection of delicate body parts is an important function of some of the bones. The skull, which protects the brain and several of the most important sensory organs (eye and ears).
4. **Storage of Chemicals:** The bones act as a chemical bank for storing elements for future use by the body, and then the bones can withdraw these chemicals as needed.
5. **Nourishment:** The teeth are specialized bones that serve to provide nourishment for the body. E.g., incisors, canines
6. **Sound Transmission:** The three smallest bones in the body are the Ossicles. They act as levers that provide impedance matching. They form a system for converting sound vibration in the air into sound vibration.
7. **Red Blood Cell Generation:** The stem cells in the bone marrow generate the RBCs.

Physics Laws of Elasticity in the Human Body:

Young's Modulus:

Young's Modulus of Elasticity: is a mechanical property of solid materials that measures the tensile or compressive stiffness when a force is applied. Young's modulus is defined as the ratio of the stress (force per unit area) applied to the object and the resulting strain (displacement or deformation) in the linear elastic region of the material. Young's modulus is meaningful only in the range in which the stress is proportional to the strain, and the material returns to its original dimensions when the external force is removed. As stresses increase, the material may flow, undergo permanent deformation, or finally break.

Hook's Law:

Hooke's Law: is the law of elasticity; it states that the force needed to extend or compress a spring by some distance. The displacement or size of the deformation is directly proportional to the deforming force. Under these conditions, the object returns to its original shape and size upon removal of the force. Figure 1 shows Hooke's law. Since the direction of the restoring force is opposite to that of the displacement, the formula for Hooke's Law is:

$$F = - KX \ldots\ldots (1)$$

Where:

F: is the force

K: is the spring constant

X: is the displacement.

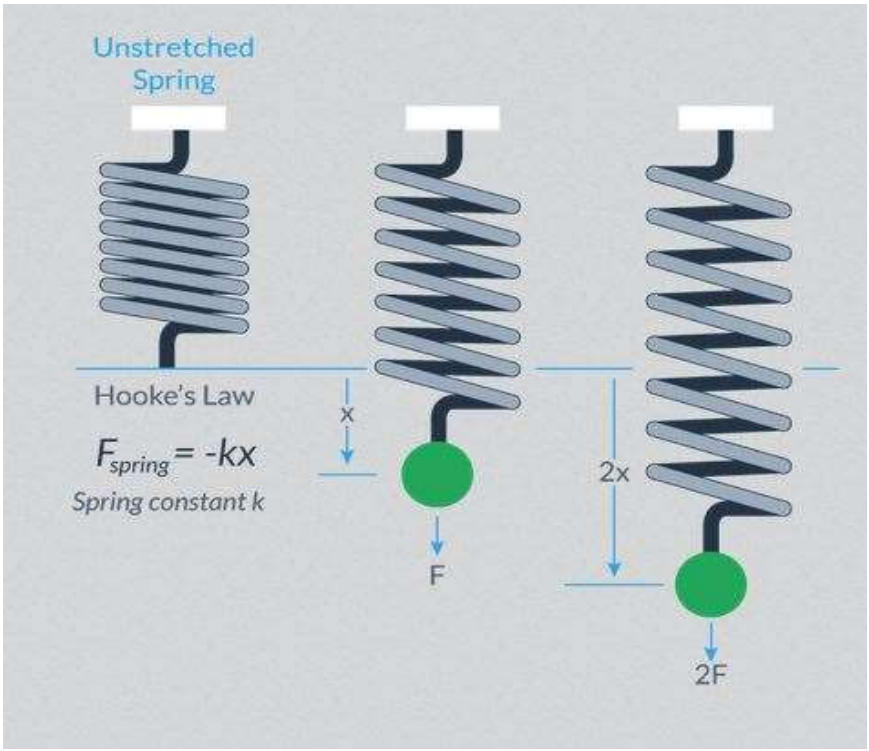

Figure (1): Shows Hooke's Law.

The Physical Applications of Hook's Law in Medicine:

Hook's law has several medical applications, especially in the fields of medicine, orthopedics, and biomechanics, such as:

- In Medicine, Hook's law has its physiological applications, which help explain the tension-length relationship of the heart by revealing that the greater the force of the myocardial contractility, the greater the stretch of the myocardial fibers
- In Orthopedics, Hook's law is used to understand the behavior of bones, tendons, and ligaments under different forces, which is important for designing implants and prosthetics
- In Biomechanics, it helps in understanding the elasticity of soft tissues and the response of the musculoskeletal system to various mechanical loads, which is crucial for designing rehabilitation programs and predicting the outcome of certain injuries or surgeries.

Hooke's Law and Breast Tissue Implant:

The elastic tissue of the breast is symbolized by a spring with a constant K. In a static, upright posture, the weight of an implant will displace the breast downward with a force proportional to the weight of the implant.

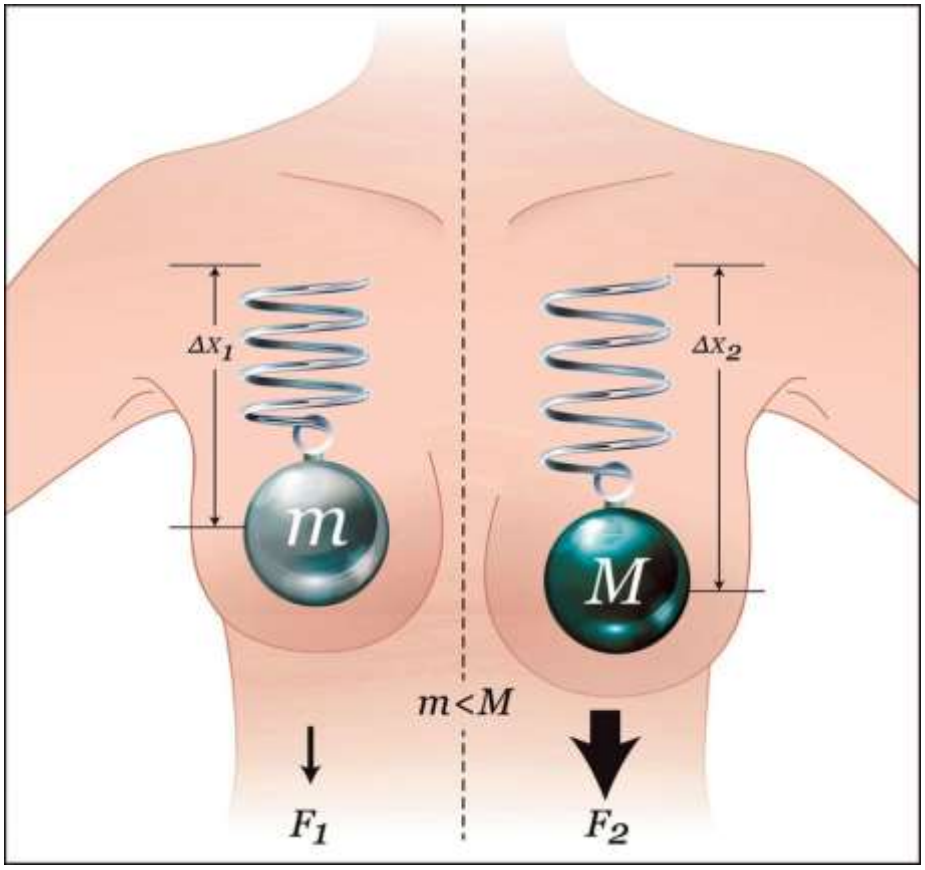

Figure (2): Shows the breast tissue stretch.

The tissue's stretch is linear (within the elasticity limits of the tissue), and, therefore, tissue displacement will increase in direct correlation with implant weight. Figure 2 shows the breast tissue stretch. A heavier implant will result in increased forces and consequential stretching of the breast as compared with a lighter implant.