University of Mosul

College of Science

Department of Physics

Second stage

Lecture 2

Sound and wave Motion

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Lecture 2:wave motion

Preparation

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Basic Concepts in Wave Motion

Means of Motion Transmission: Energy can be transferred in nature through two ways: either through the transfer of matter or through the transfer of waves. In the first method, energy is transferred from one place to another along with the transfer of matter, meaning that the transfer of energy is accompanied by a transfer in mass. As for the second method, energy is transferred from one location to another through waves, without being accompanied by a transfer in mass. Waves can travel through a medium or without a medium, depending on the nature of the wave. Examples of waves that travel through a medium include sound waves in the air or waves on the surface of water. These waves cannot travel in a vacuum. On the other hand, electromagnetic waves and light waves are examples of waves that can travel through a vacuum.

Wave Motion: Vibratory motion is the movement made by a body oscillating on either side of its original position of rest or equilibrium, such as the simple pendulum motion. It also refers to the disturbance or motion that occurs within a medium as each part of its vibrating parts moves successively from one point to another. This vibratory motion is called simple harmonic motion in its purest form.

Types of wave motion:

Wave motion can be divided into three main types:

Mechanical wave motion: It is the movement that requires a medium to propagate, and this medium can be solid or liquid. Examples of these waves include sound waves, waves on the surface of water, seismic waves, waves propagating through wires and metal rails, waves in vibrating strings, waves in thin membranes and vibrating sheets, and waves in building structures and machinery.

Electromagnetic wave motion -: It is the kind of motion that does not require a material medium for its propagation. It can travel through a vacuum as well as some material media, such as all electromagnetic spectrum waves like radio waves, television waves, radar waves, microwaves, infrared rays, visible light, and ultraviolet rays.

Wave motion involving matter: It is the wave quality associated with the movement of matter particles. Studies on electron diffraction indicated. A moving particle is associated with a wave. Therefore, a particle with mass “m” and moving with speed “u” has an associated wavelength. It is important to note that Planck's constant, denoted by h, is 6.626 x 10-43 J/s.

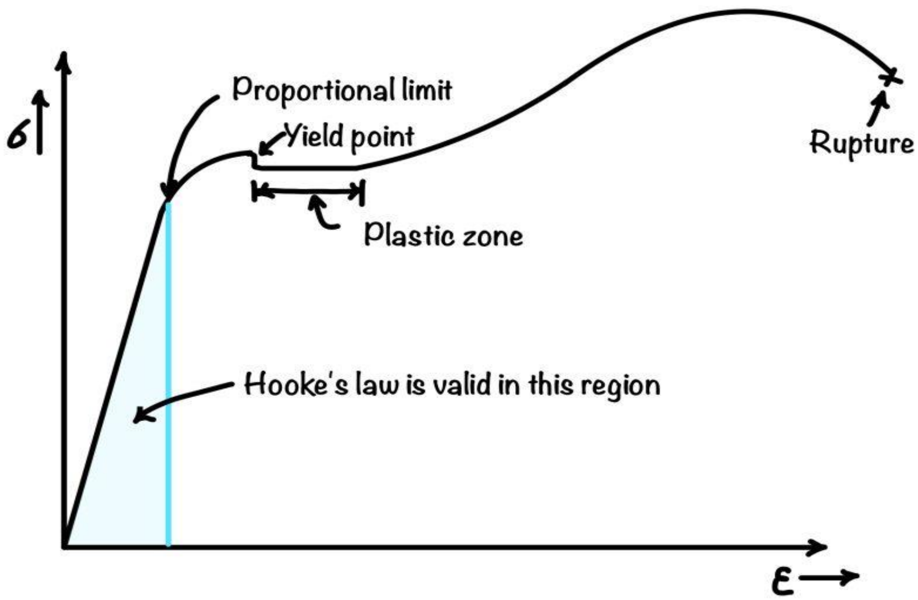
In the next chapter, the main focus will be exclusively on the mechanisms of mechanical wave motion, of which sound is one of the most important aspects.

The basic properties of the transmission of mechanical wave motion :-

The transmission of wave motion in any material medium is attributed to two fundamental properties of that medium: elasticity and Inertia.

The property of elasticity The matter relates to the ability of a material to resist deformation and regain its shape, size, or position once the deforming force is removed. The law governing the behavior of these materials is known as Hooke's law, For example When a wire is subjected to a pulling force and then elongated due to the pulling force. This elongation occurs as a result of the molecules moving away from each other in the same direction as the applied force.

At the same time, the cross-sectional area changes. Therefore, the cohesive force between the molecules tries to return the wire to its original state after applying the external tensile force, or deformation force. The total elongation of a length of wire is directly proportional to the tensile force, forming the basic formula of Hooke's Law. but, if the deformation force exceeds a certain threshold and the spacing between molecules exceeds the elastic limit, the molecules fail to return to their initial positions when the effective force is removed. As a result, the wire loses its elasticity and fails to return to its original length.



Stress-strain curve for mild steel under uniaxial tension

Hooke's Law can be expressed in terms of stress and plasticity (compliance). which is defined as the force applied to unit areas of the surface subjected to that force.

Stress = force / area

As for strain, it is the ratio between the amount of deformation in the body caused by the deforming force over its original dimension before the deformation.

Strain (Compliance) = amount of deformation/original dimension

The relationship between stress and plasticity within the *limits of elasticity* is as follows:

strain ∝ stress

Compliance x constant = stress

The constant is the *modulus of elasticity* and thus it is appropriate for Hooke's law.

Modulus(coefficient) of elasticity = stress/elasticity

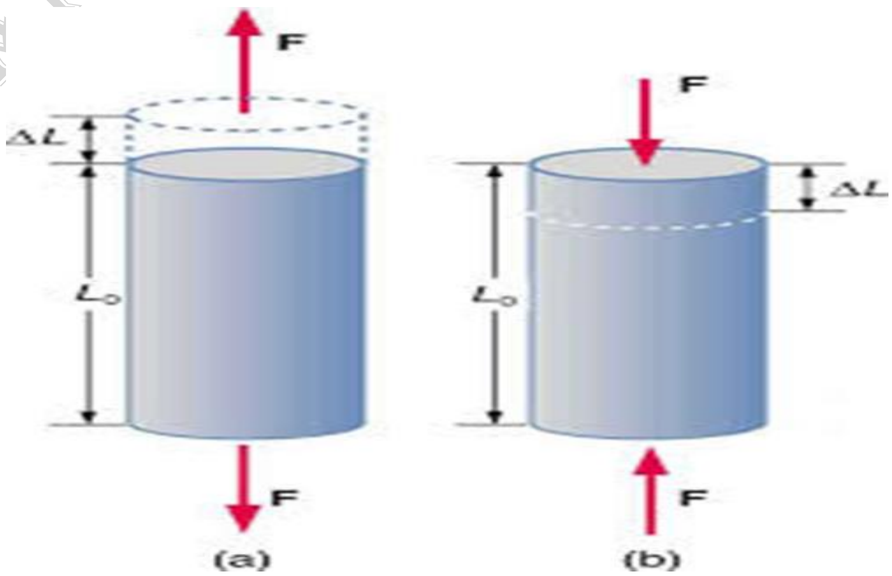
There are three different types of *modulus of elasticity*, each of which depends on the nature of the material, geometry, and type of deformation What is caused by the deforming force:

First: the linear modulus of elasticity

Second: volumetric

Third: hardness coefficient

The linear elasticity coefficient, also known as the Young's modulus Y, refers to the measure of a wire's ability to deform when subjected to a force F. If we have a wire with an initial length L_0 and it is affected by a deforming force F, the length of the wire will change by an amount of ΔL.



Longitudinal strain is $= \frac{\Delta L}{L_\circ}$

The longitudinal stress is= $\frac{F}{A}$

The Young's modulus is the ratio between stress to plasticity within elastic limits.

$$Y = \frac{F}{A} / \frac{\Delta L}{L_\circ}$$

**The deforming force (tensile force) is directly proportional to the longitudinal deformation (elongation) ΔL.*

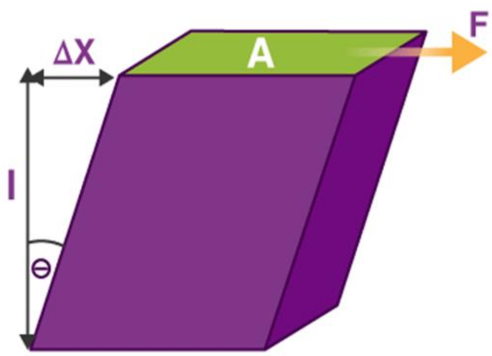
Volume modulus (coefficient) of elasticity: This coefficient corresponds to the volumetric deformation that occurs in fluids, specifically liquids and gases. Therefore, when the volume of a fluid is subjected to a certain pressure denoted by V_0, an increase in pressure by ΔP will cause a decrease in the volume of the fluid by ΔV. The pressure rise ΔP refers to the increasing (augmentation) force applied uniformly and perpendicularly over the entire surface area of the liquid, which can be represented by F / A. Here, F represents the increase in force, while A represents the surface area of the fluid. Thus, ΔP symbolizes the pressure experienced by the fluid, and the ratio between the volume change ΔV and the original volume V_0 is an indication of volumetric plasticity. If we denote the volumetric modulus of elasticity by K, then....

$$K = \frac{\Delta P}{\Delta V / V_\circ} = V_\circ \frac{\Delta P}{\Delta V}$$

Since the quantities K, A, and V_0 are constants, we get $F \propto \Delta V$ That is, the deforming force ($F = A\,\Delta p$)is directly proportional to the volumetric deformation.

The coefficient of Hardness (rigidity) This parameter represents the deformation that occurs in the geometric shape of a solid body, without any change in volume. If there is a solid cube with face A fixed at the bottom as shown in the figure, and a transverse force of magnitude F is applied to one of the faces, called the shear force, it is responsible for causing the deformation, which is measured by the angle θ. This angle, which is referred to as shear ductility, is a measure of the degree of distortion caused by a shear force. The shear modulus, or hardness modulus, is determined as the ratio of shear stress F/A to shear ductility (θ), and is called the shear modulus and is represented by the symbol n.

$$n = \frac{F/A}{\theta}$$



Shear Modulus

*F∝ θ to produce constants A , n where That is, the deforming force F is directly proportional to the shear deformation θ.

The general formulation of Hooke's law can be described as follows:

"The deforming force is directly proportional to the magnitude of the deformation within the limits of flexibility".

Poisson ratio, symbolized by σ, is an important quantity in elasticity. It is defined as the ratio between the transverse and longitudinal flexibility. For example, if we have a regular cylindrical string of rubber with a length of L_0 and a diameter of D_0, when a tension force is applied, its length increases by (ΔL) and its diameter decreases by (ΔD).

$$\sigma = \frac{\Delta D / D_\circ}{\Delta L / L_\circ}$$

The modulus of elasticity n, K, Y and the Poisson ratio(σ) are related to each other according to the following relationship:

$$Y = 2n(1+\sigma)$$

$$K = \frac{Y}{3(1-2\sigma)}$$

The property of inertia : The concept of inertia represents the ability of a body to maintain its motion unless acted upon by an external force. This principle, known as the continuity principle, states that an object will remain at rest or in motion unless acted upon by an external force. Anybody is described in terms of the amount of its matter, which is known as mass. The mass of an object determines its resistance to changes in motion, and thus its inertia. Mass is a quantitative measure of inertia.

The property of continuity or inertia of any body is often expressed as mass per unit volume, i.e. density. Therefore, the inertia of any material medium increases with an increase in its density, meaning that the density of the medium determines the effect of the force acting on it. The greater the density of the medium, the less its response to the influence of the external force on it to change its state of motion..