

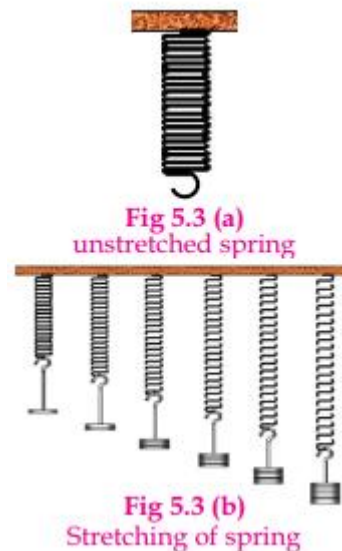
5 Deformation of Solids

5.1 Hook's law

5.1.1 Illustrate That Force May Produce A Change In The Size And Shape Of An Object

Force is a push or a pull that changes or tends to change the state of rest or uniform motion of an object or changes the direction or shape of an object. Solids have definite shapes and sizes; however, it is possible to change their shapes and sizes by applying external forces. When the external force is removed, the object tends to return to its original shape and size. This behaviour is called elastic behaviour. Solids can be stretched, squashed, bend or twisted. A sufficiently large force will permanently deform or break an object.

As springs are designed to stretch a long way when force is applied, therefore it is easy to measure changes in their lengths. Consider a spring hung from a rigid support, so that its top end is fixed. Weights are hung on other end of the spring. These are called load. As load is increased, the spring is stretched and its length increases. When the load is removed, the spring returns to its original length. This is called elastic change.



When the load is increased in regular steps the length of the spring also increases simultaneously. If the load is increased greatly, the spring will change its shape permanently. The length of spring increases as the force (load) increases. This increase in length of spring is known as extension.

5.1.2 State Hooke's Law

Robert Hooke, an English scientist first described the mathematical pattern of stretching a spring. He observed the dependence of displacement or size of the deformation upon the deforming force or load. Hooke's law states that:

Within elastic limit, the displacement produced in the spring is directly proportional to the force applied.

Mathematically if 'F' is the applied force and 'x' is the displacement (extension) in the spring then the equation for Hooke's law may be written as:

$$F \propto x$$

$$F = kx$$

where k is spring constant (stiffness of spring). Hooke's law is applicable to all kinds of deformation and all types of matter i.e., solids, liquids or gases within certain limit. This limit tells the maximum force or stress that can be safely applied on a body without causing permanent deformation in its length, volume or shape. In other words, it is a limit within which a body recovers its original length, volume or shape after the deforming force is removed. Beyond this limit spring deforms permanently.

5.1.3 Define Spring Constant

The spring constant is a measure of how stiff or strong a spring is. It tells you how much force is needed to stretch or compress a spring by 1 metre.

5.1.4 Solve Word Problems Using The Relation $k = F/x$

Practice questions available in worksheet.

5.1.5 Describe Applications Of Hook's Law In Measuring Instruments

Hooke's law serves as the basic principle in wide range of applications. In the field of technology and engineering, springs in many devices rely on Hooke's law for their functions such as spring scales, balance wheel of the mechanical clocks, galvanometer, suspensions system in vehicles and motorbikes, door hinges, mattresses, material testing machines, etc.

However, Hooke's law applies within a specific range of forces. Exceeding the range or limit results in permanent deformation and no longer follows Hooke's law. Some of the uses are elaborated below.

Spring scales

Spring scales use the extension or compression of a spring to determine the weight of objects. In a common spring balance, the extension or elongation produced is a measure of the weight in compression balance, the spring is compressed by the load (force) and the compression produced is measured by means of a pointer moving over a scale. Weighing machine usually use this type of balance.

Balance wheel of mechanical clocks

The balance wheel in mechanical clocks use spring to control the back-and-forth motion that regulates the speed of the hands of a clock.

Galvanometer

Galvanometer is a current detecting device. It makes use of a tiny spring called hair spring which provides electrical connections to the galvanometer coil and also restores the pointer back to zero position. The deflection of the pointer is proportional to the current flowing through it within the range.

5.1.6 Interpret Load Extension Graphs For Elastic Solids

The way a material responds to a given force can be shown on a force-extension graph. Every material will have a unique force-extension graph depending on how brittle or ductile it is. A material may obey Hooke's Law up to a point. This is shown on its force-extension graph by a straight line through the origin. As more force is added, the graph may start to curve slightly. The key features of the graph are:

1. The point beyond which Hooke's law is no longer true when stretching a material i.e. the extension is no longer proportional to the applied force. The point is identified on the graph where the line starts to curve.
2. The force constant k is the force per unit extension up to the limit of proportionality, after which the material will not obey Hooke's law. This is the gradient of the straight part of the graph.
3. The graph might also include the elastic limit, this is, "the maximum amount a material can be stretched and still return to its original length" (above which the material will no longer be elastic). This point is always after the limit of proportionality.
4. Therefore, k is the gradient of the linear part of the graph i.e. where Hooke's Law is obeyed.

