Deformation of solids

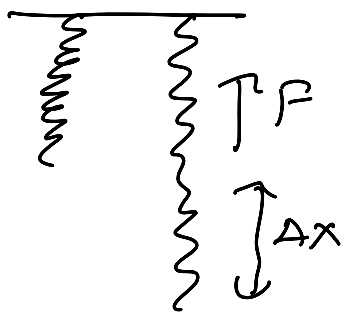
Deformation → When forces are applied to a solid body, its shape changes. This change is called deformation.

1) Tensile deformation
2) Compressive deformation

Elastic Limit → The maximum value of the applied force up to which the body remains perfectly elastic, that is it regains its original length after the force is withdrawn is called the elastic limit.

Plastic deformation → Beyond elastic limit, if the force is withdrawn, stretched object does not regain its original length and is permanently deformed.

Hooke's Law → The force exerted by the stretched object is proportional and opposite to it's extension within the elastic limit.

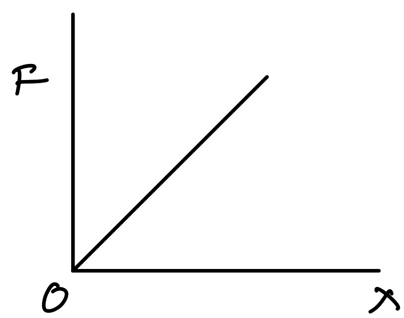


$F \propto -\Delta x$

$F = -kx$

$k =$ spring constant

the force exerted by the spring is in opposite direction to the extension



$k = \frac{F}{x}$

Work done = Avg force × distance

$= \left(\frac{0+f}{2}\right) \times \Delta x$

$= \frac{1}{2} F x$

Energy stored in a deformed Object = Area under the graph = $\frac{1}{2} Fx$

Elastic potential energy = $\frac{1}{2} Fx$

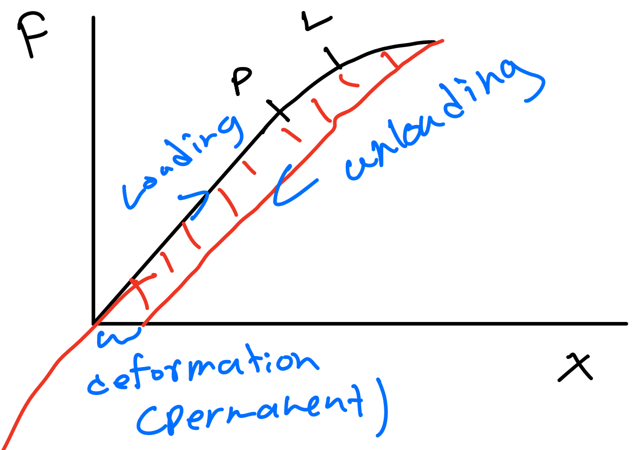
$\Rightarrow \frac{1}{2} k x \times x$

$$\Rightarrow \boxed{\frac{1}{2} k x^2}$$

Factors affecting extension

i) extension $\propto$ Force

ii) extension $\propto \dfrac{1}{\text{Area of cross-section}}$

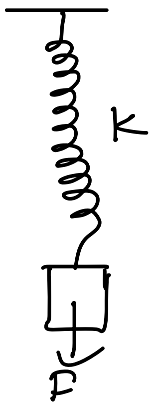


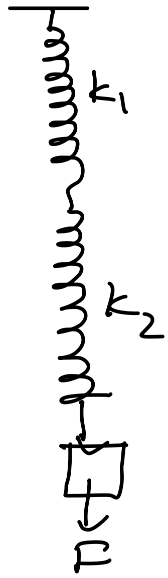
P = Proportionality limit
(upto which Hooke's law is obeyed)

L = Elastic Limit
(the limit of force upto which the spring retains its original length)

Heat energy is lost in the spring

Springs in Series





$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$$

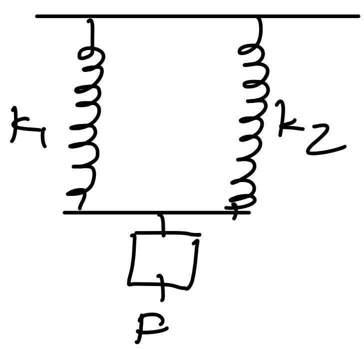
$$k_{eq} = \frac{k_1 k_2}{k_1 + k_2}$$

$$\frac{1}{k_{eq}} = \frac{1}{k} + \frac{1}{k}$$

$$\frac{1}{k_{eq}} = \frac{2}{k}$$

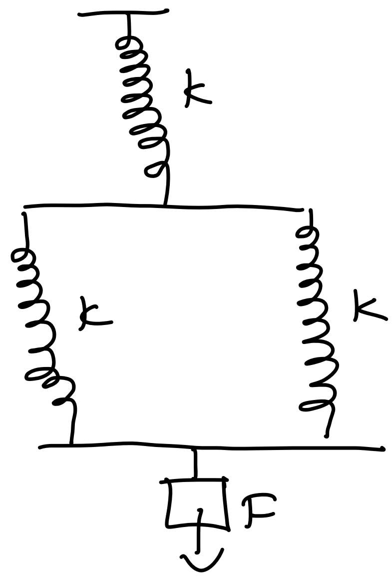
$$k_{eq} = \frac{k}{2}$$

Spring in parallel



$$k_{eq} = k_1 + k_2$$

Example



$2k$

$$\frac{1}{k_{eq}} = \frac{1}{2k} + \frac{1}{k}$$

$$k_{eq} = \frac{2}{3} k$$

Tensile stress

The tensile force per unit are is called the tensile stress.

$$\text{tensile stress} = \frac{\text{tensile force}}{\text{area of cross section}}$$

$$\sigma = \frac{F}{A}$$

unit → $N m^{-2}$ or Pa

→ compressive stress
→ shear stress

Tensile strain

The extension per unit length is called tensile strain.

$$\text{Tensile strain} = \frac{\text{extension}}{\text{original length}}$$

$$\varepsilon = \frac{\Delta L}{L} \quad \text{(no unit)}$$

Strength → the ability of a material to with stand stress is called strength.

Tensile strength → the tensile strength of a material is the tensile stress at which a material breaks.

Ultimate tensile stress →
the maximum stress a wire can support is called ultimate tensile stress.

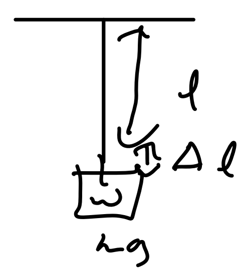
Young Modulus

The ratio of stress with strain is called Young Modulus of the material.

$$\text{Young Modulus (E)} = \frac{\text{Stress } (\sigma)}{\text{strain } (\epsilon)}$$

$$E = \frac{\sigma}{\epsilon}$$ unit $\rightarrow Nm^{-2}$ or Pa

$$\Rightarrow E = \frac{\frac{F}{A}}{\frac{\Delta l}{l}} = \frac{Fl}{A\Delta l}$$



$$E = \frac{mgl}{\pi r^2 \Delta l}$$

mg → weight
l = original length
Δl = extension
r = radius

$$e \propto \frac{1}{A}$$