### Spring Force

Hooke’s Law gives the force:

\[ F = -kx \]

- \( k \) is the spring constant
- \( F \) is the restoring force
- \( F \) is in the opposite direction of \( x \)
- \( k \) depends on how the spring was formed, material from which it was made, thickness of the wire, etc.

### Spring Work

\( F \) varies with \( x \):

\[ W = \int_{x_i}^{x_f} F \, dx \] only good if \( F \) constant.

Approximate with steps of rectangles:

\[ \text{area under curve} = \text{sum of areas of rectangles} \]

Linear spring is simple:

\[ A = \frac{1}{2} Bh \Rightarrow W = \frac{1}{2} x_{\text{max}} F_{\text{max}} = \frac{1}{2} k x^2 \]

= work done on spring

### Potential Energy in a Spring

\[ \text{Elastic Potential Energy} \]

\[ \text{– related to the work required to compress spring from its equilibrium position to some final, arbitrary position } x \]

\[ \text{Work } = \text{Potential Energy} \]

Initial and final kinetic energies = 0

### Work with Spring + Gravity

\[ W_{nc} = (KE_f - KE_i) + (PE_g_f - PE_g_i) + (PE_s_f - PE_s_i) \]

- \( PE_g \) is the gravitational potential energy
- \( PE_s \) is the elastic potential energy associated with a spring
- \( PE \) will now be used to denote the total potential energy of the system

#### Conservation of Energy: Spring + Gravity

- The PE of the spring is added to both sides of the conservation of energy equation
- The same problem-solving strategies apply

\[ (KE + PE_g + PE_s)_f = (KE + PE_g + PE_s)_i \]

### Spring + Gravity-Conservative System

\[ (KE + PE_g + PE_s)_i = (KE + PE_g + PE_s)_f \]

- \( PE_g \) is the gravitational potential energy

\[ PE_g = mgh \]

- \( PE_s \) is the spring potential energy

\[ PE_s = \frac{1}{2} kx^2 \]

### Nonconservative Forces and Energy

\[ W_{nc} = (KE_f - KE_i) + (PE_j - PE_f) \]

or

\[ W_{nc} = (KE_f + PE_i) - (KE_i + PE_f) \]

The energy can either cross a boundary or the energy is transformed into a form of non-mechanical energy such as thermal energy (friction or direct collisions)