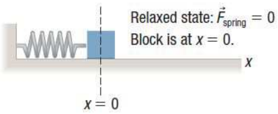
SPH4U UNIVERSITY PHYSICS

ENERGY & MOMENTUM

☞ Elastic Potential Energy (P.192-196)

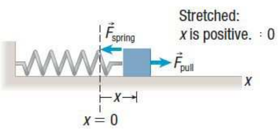
Spring Forces

One important type of potential energy is associated with springs and other elastic objects. In a relaxed state, with no force applied to its end, the spring is at rest.



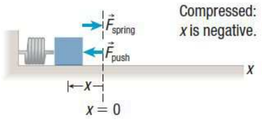
Spring Forces

Suppose you pull on the spring with a force F_{pull}*, causing the spring to stretch to the right, as shown. When stretched, the spring exerts a force* F_{spring} *to the left.*



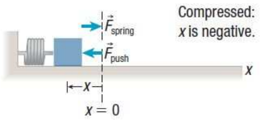
Spring Forces

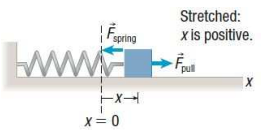
*Likewise, if you push on the spring with a force **F_{push}**, it compresses to the position shown. When compressed, the spring exerts a force **F_{spring}** to the right.*



Spring Forces

*According to Newton's third law of motion, the force exerted by the object that is applying the force to the spring is equal and opposite to the force that the spring exerts on that object. In both cases, **F_{spring}** is called the **restorative force** because it tends to restore the spring to its natural length.*

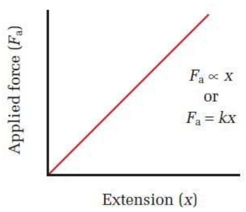




Spring Forces

NOTE!

The amount of force exerted by a spring is proportional to the spring's displacement (Δx). This is Hooke's law, named after Robert Hooke who discovered the relationship in 1678.



Hooke's Law

HOOKE'S LAW

$$F_x = k\Delta x$$

where F_x is the force exerted by the spring (N) → *restoring force*
k is the spring constant (N/m) → *spring stiffness*
Δx is the displacement of the spring from its rest position (m)

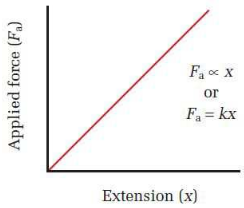
NOTE!
The direction of F_x is opposite to the direction of the displacement

Hooke's Law

PRACTICE

1. Use the F-x graph given to answer the following questions.
   (a) What does the slope of the graph represent?

   (a) the spring constant "k"

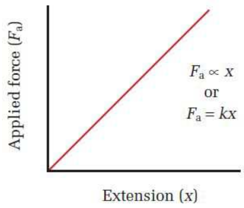


Hooke's Law

PRACTICE

1. Use the F-x graph given to answer the following questions.
   (b) As the stiffness of the spring increases, what happens to the graph?

   (b) as stiffness ↑ , k ↑ , slope ↑



Hooke's Law

PRACTICE

2. A typical compound archery bow requires a force of 133 N to hold an arrow at "full draw" (pulled back 71 cm). Assuming that the bow obeys Hooke's law, what is its spring constant?

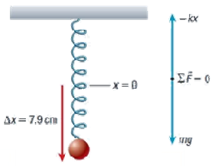
   k = 190 N/m

Hooke's Law

PRACTICE

3. A spring hangs at rest from a support. If you suspend a 0.46 kg mass from the spring, its deflection is 7.9 cm
   (a) Determine the spring constant.

   (a) k = 57 N/m

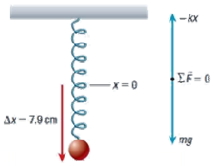


Hooke's Law

PRACTICE

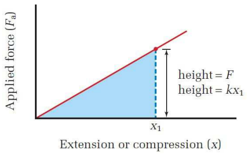
3. A spring hangs at rest from a support. If you suspend a 0.46 kg mass from the spring, its deflection is 7.9 cm
   (b) Calculate the displacement, in centimetres, of the same spring when a 0.75 kg mass hangs from it instead.

   (b) Δx = 13 cm



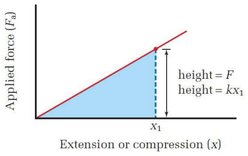
Elastic Potential Energy

A graph of Hooke's law not only gives information about the forces and extensions for a spring (or any elastic substance), you can also use it to determine the quantity of potential energy stored in the spring.



Elastic Potential Energy

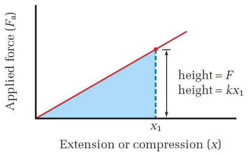
As discussed previously, the amount of work done can be determined by finding the area under a force-versus-position graph. A Hooke's law graph is such a graph, since extension or compression is simply a displacement.



Elastic Potential Energy

The area under the F-x graph for a spring, therefore, is equal to the amount of elastic potential energy stored in the spring.

E_E = area under F-x graph

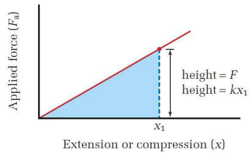


Elastic Potential Energy

PRACTICE

4. Find an expression for the area under a F-x graph for a perfectly elastic spring.

   $E_e = ½kx^2$



Elastic Potential Energy

ELASTIC POTENTIAL ENERGY (E_e)

- energy possessed by a perfectly elastic material

$$E_e = \frac{1}{2}k\Delta x^2$$

where E_e is the elastic potential energy of the spring (J)
k is the spring constant (N/m)
Δx is the displacement of the spring from its rest position (m)

Elastic Potential Energy

PRACTICE

5. A spring with a spring constant of 75 N/m is resting on a table.
   (a) If the spring is compressed a distance of 28 cm, what is the increase in its potential energy?
   (b) What force must be applied to hold the spring in this position?

   (a) $\Delta E_e = 2.9$ J
   (b) $F_x = 21$ N

Elastic Potential Energy

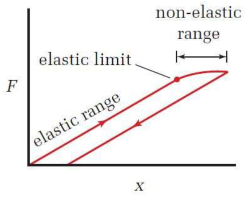
PRACTICE

6. A 5.3 kg mass hangs vertically from a spring with a spring constant of 720 N/m. The mass is lifted upward and released. Calculate the force and acceleration on the mass when the spring is:
   (a) compressed by 0.36 m.
   (b) stretched by 0.36 m.

   (a) F_x = 310 N [down]; a = 59 m/s^2 [down]
   (b) F_x = 210 N [up]; a = 39 m/s^2 [up]

Elastic Potential Energy – DYK?

A perfectly elastic material will return precisely to its original form after being deformed. However, no real material is perfectly elastic. Each material has an elastic limit, and when stretched beyond that limit (into the plastic region), the material will not return to its original shape. As a result, the material becomes permanently deformed.



✔ Check Your Learning

TEXTBOOK

P.200 Q.3-5 (Review)