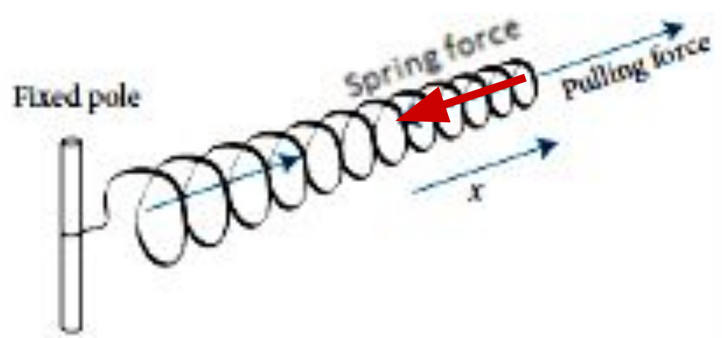
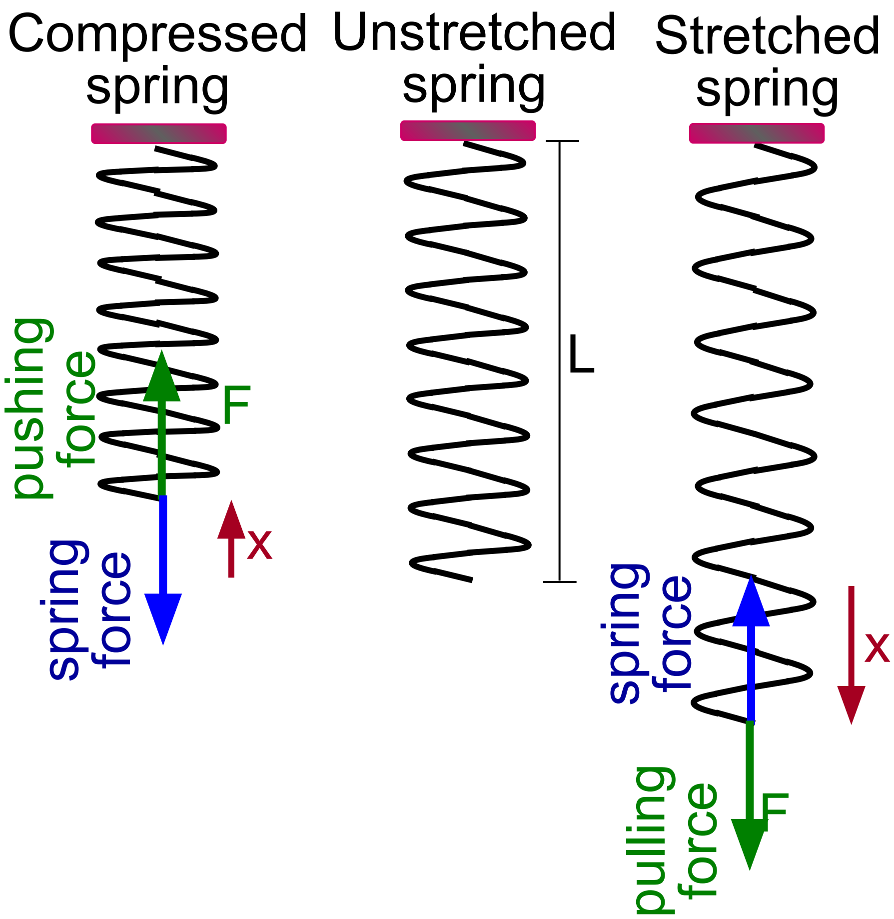
Spring/Tension force – Hooke's law

- Holding one end and pulling the other produces a *tension (spring) force* in the spring.
- You'll notice as you pull the spring, that the further you extend the spring, then the greater the force that you have to exert in order to extend it even further.
- As long as the spring is not stretched beyond a certain extension, called *elastic limit,* the force is directly proportional to the extension.
- Beyond this point the proportionality is lost.
- If you stretch it more, the spring can become permanently deformed in such a way that when you stop pulling, the spring will not go back to its original length.





In the region of proportionality we can write

$$F = kx$$

k is a constant whose value depends on the particular spring.
For this reason *k* is called the spring constant.
It measures stiffness of the spring in Newtons per metre.

Example:

k = 20 N/m
L = 10 cm

How much force do you have to exert if you want to extend the spring for

a. 1 cm
b. 2 cm
c. 3 cm

a. F = kx = (20 N/m)(0.01 m) = 0.2 N
b. F = kx = (20 N/m)(0.02 m) = 0.4 N
c. F = kx = (20 N/m)(0.03 m) = 0.6 N

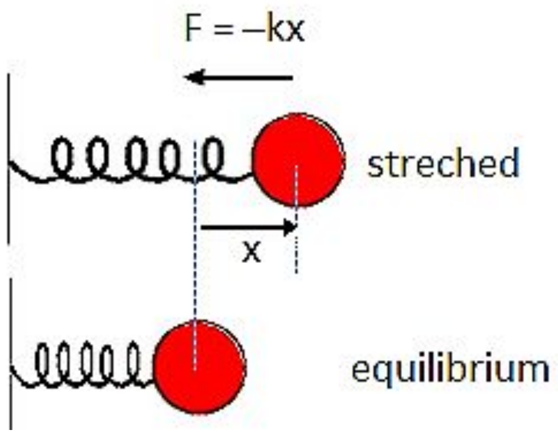
} proportionality

Note: The spring force has the same value, but it is in the opposite direction !!!!!

Spring force – Hooke's law: $F = -kx$

The spring force is the force exerted by a compressed or stretched spring upon any object that is attached to it.

Note: The spring force has the same value, but it is in the opposite direction !!!!!

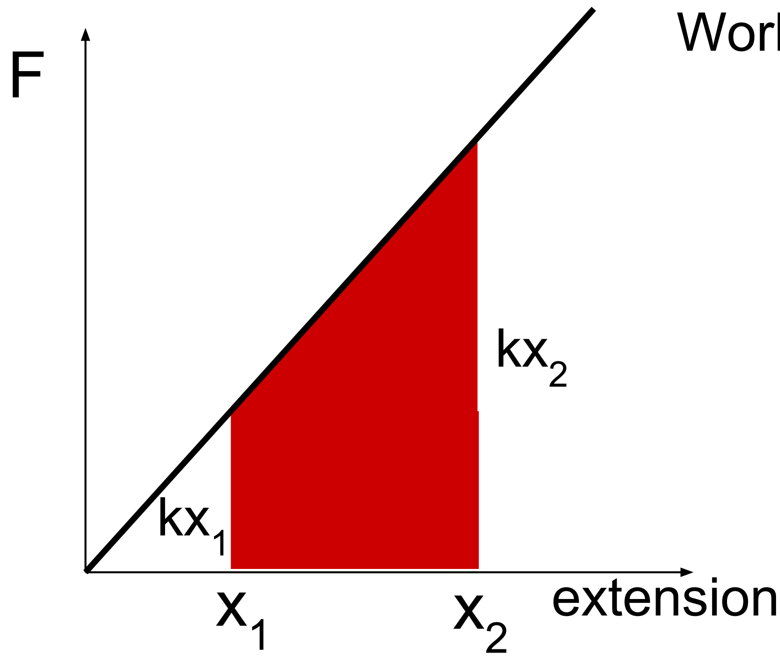


x is the displacement (extension/compression) of the spring's end from its equilibrium position

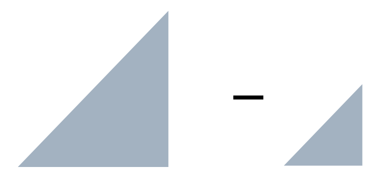
F is the spring force exerted by the spring

k is a constant called *spring constant* (in SI units: N/m).

The work done by a non-constant applied force on a Hooke's spring is found from the area under the graph F *vs.* x



Work done by a force F = kx when extending a spring from extension x_1 to x_2 is:



$$W = \frac{1}{2}(kx_2 \cdot x_2) - \frac{1}{2}(kx_1 \cdot x_1)$$

$$W = \frac{1}{2}k(x_2^2 - x_1^2)$$

Work done by a force F = kx when extending a spring from extension 0 to x is:

W = ½ kx^2

Energy, E

In physics energy and work are very closely linked; in some senses they are the same thing. If an object has energy it can do a work. On the other hand the work done on an object is converted into energy.

work done = change in energy

$$W = \Delta E$$

Elastic pote

- If some for tension x, the work done by that force i ransfer of energy, we say that the er e spring, and that work is now storec tic potential energy.

- EPE = ½

- A spring c sed. The same mathemati r compressing springs.

Just imagine how much energy is stored in the springs of this scale.

Units

$W = Fd$ $(W) = (1N)(1m) = 1\ kg\ m^2\ s^{-2} = 1\ J$

$PE = mgh$ $(PE) = (1kg)(1\ m\ s^{-2})(1m) = 1\ kg\ m^2\ s^{-2} = 1\ J$

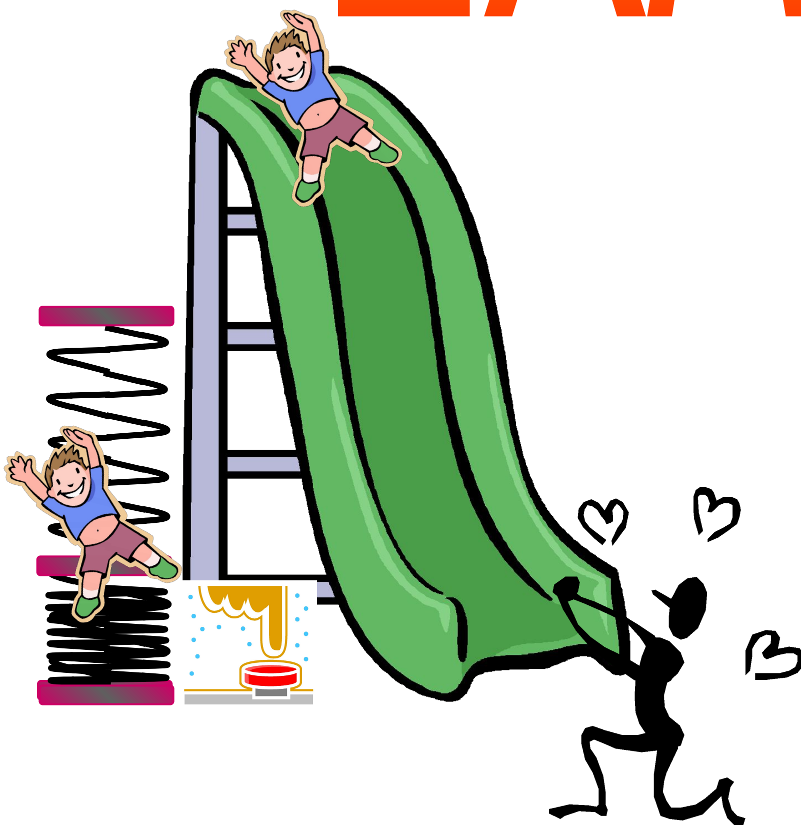
$EPE = \frac{1}{2} kx^2$ $(EPE) = (1N/1m)(1m^2) = 1\ kg\ m^2\ s^{-2} = 1\ J$

$KE = \frac{1}{2} mv^2$ $(KE) = (1kg)(1m/s)^2 = 1\ kg\ m^2\ s^{-2} = 1\ J$

Even in units we see that the work and energy are equivalent.

EXAMPLE

Work is a way of transferring energy from one form to another, but itself is not a form of energy. All types of energies and work have the same units. Everything can be transformed into each other.



When work is done on an object, energy is transferred to that object.

Example: A spring at the bottom of a slide is compressed by an external force. A parent releases the spring when a child sits on it. EPE is transferred to the child by spring force doing the work which is transformed into KE of the child. On the way up, KE is being transformed into PE.

This energy is what enables that child to then do work. How? First that PE has to be transformed back into KE – child slides down a slide – KE of the child can do work on the waiting parent – it can knock him over.

Parent does the work on the ground.