AP Physics I

Energy

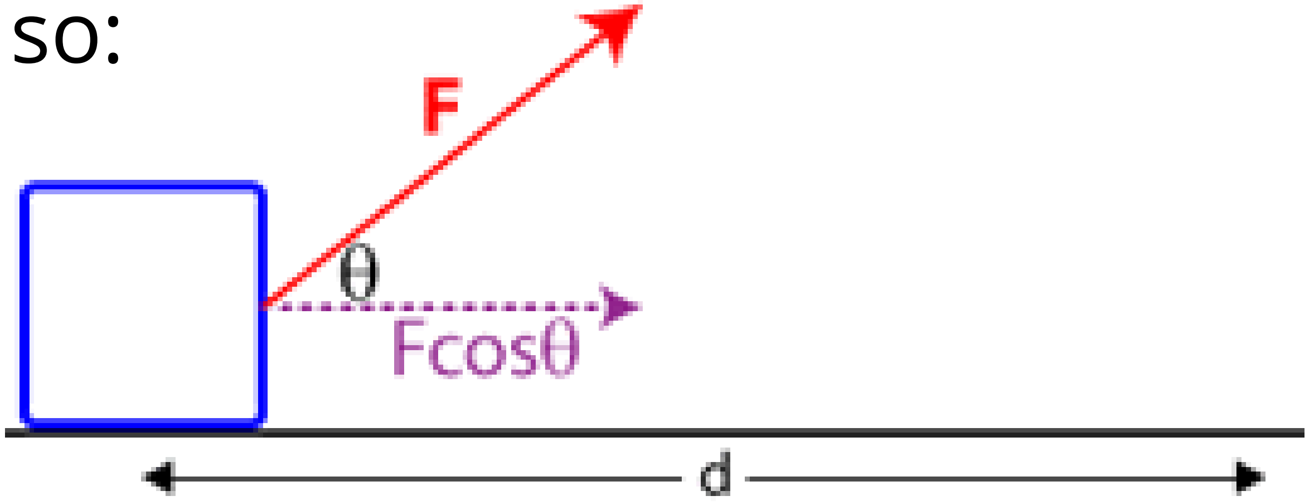
Work

Work -- the process of moving an object by applying a force – transfer of energy to the object

$$W = Fd$$

Only force applied in the direction of the object's displacement counts though so:

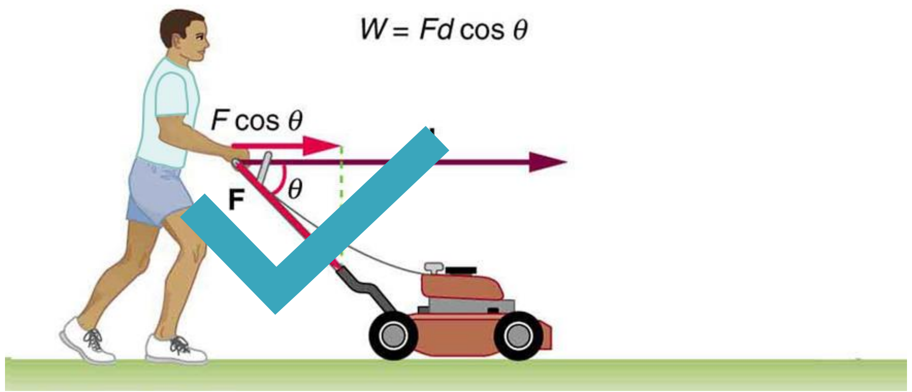
$W = F\cos\Theta d = Fd\cos\Theta$

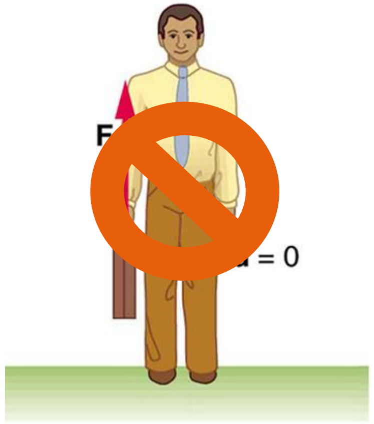


Is this work?

Example	Direction of force	Direction of motion	Doing work?
			
			
			
			

Is work happening here?





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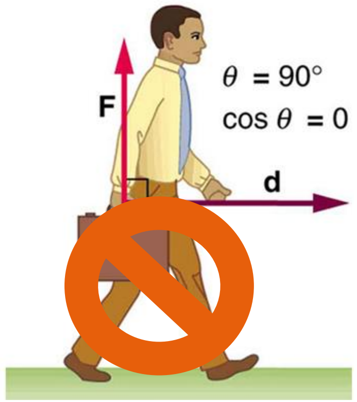
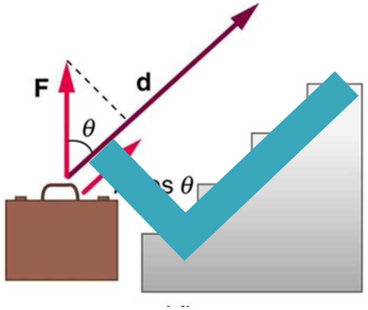
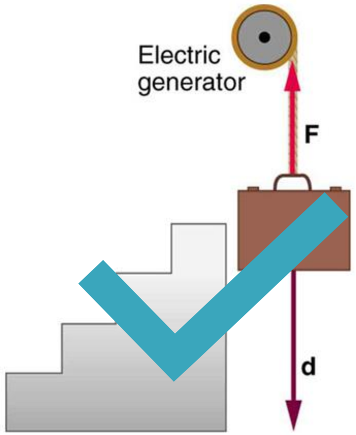






Joule

- Work and energy have the same units.
- From the definition of work – Newtons * Meters.
- In SI units, work and energy are measured in newton-meters.
- A newton-meter is given the special name joule (J), and 1J=1N·m=1kg·m2/s2.
- One joule is not a large amount of energy; it would lift a small 100-gram apple a distance of about 1 meter.

Positive or Negative? 0?

If Force or component points in same direction of displacement.

If Negative?

Force is trying to take away energy.

Pointing in opposite direction of displacement.

Perpendicular? 0!

Also 0 if no displacement!

Class Problem

Question: An appliance salesman pushes a refrigerator 2m across the floor by applying a force of 200N. Find the work done.

Answer: Since the force and displacement are in the same direction, the angle between them is 0:

$$W = Fd\cos\Theta = (200N)(2m)(\cos 0^0) = 400J$$

Class Problem

Question: A friend's car is stuck on the ice. You push down on the car to provide more friction for the tires (by way of increasing the normal force), allowing the car's tires to propel it forward 5m onto less slippery ground. How much work did you do?

Answer: You applied a downward force, yet the car's displacement was sideways. Therefore, the angle between the force and displacement vectors is 90°, so

$$W = Fd\cos\theta = Fd(\cos 90^0) = 0$$

Class Problem

Question: You push a crate up a ramp with a force of 10N. Despite your pushing, however, the crate slides down the ramp a distance of 4m. How much work did you do?

Answer: Since the direction of the force you applied is opposite the direction of the crate's displacement, the angle between the two vectors is 180°.

$$W = Fd\cos\theta = (10N)(4m)(\cos 180^0) = 40J$$

Class Problem

Question: How much work is done lifting an 8-kg box from the floor to a height 2m above the floor?

Answer: Displacement is 2m, and the force must be applied in the direction of the displacement, but what is the force?

To lift the box we must match and overcome the force of gravity on the box.

Therefore, the force we must apply is equal to the gravitational force, or weight, of the box:

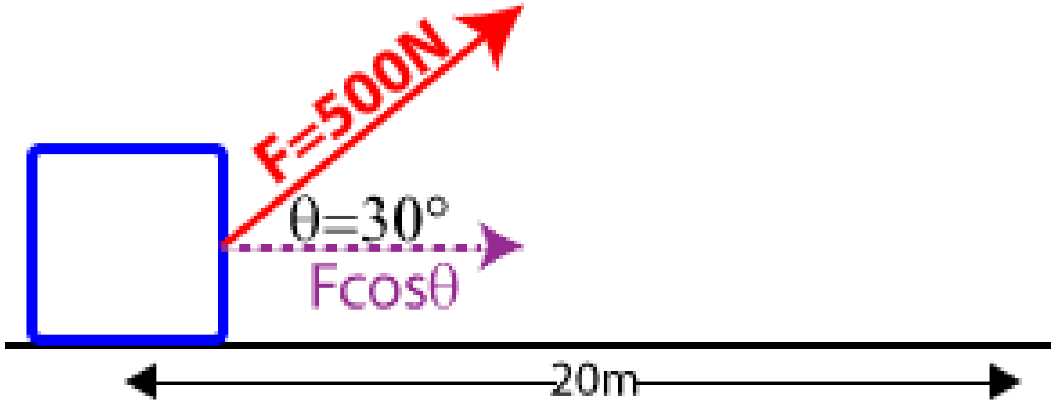
$$F = mg = (8kg)(9.81m) = 78.5N$$

$$W = Fd\cos\Theta = (78.5N)(2m)(\cos 0^0) = 157J$$

Class Problem

Question: Barry, John, and Sidney pull a 30-kg wagon with a force of 500N a distance of 20m. The force acts at a 30° angle to the horizontal. Calculate the work done.

$$W = Fd\cos\theta = (500N)(20m)(\cos 30^0) = 8660J$$



Force vs. Displacement Graphs

The area under a force vs. displacement graph is the work done by the force.

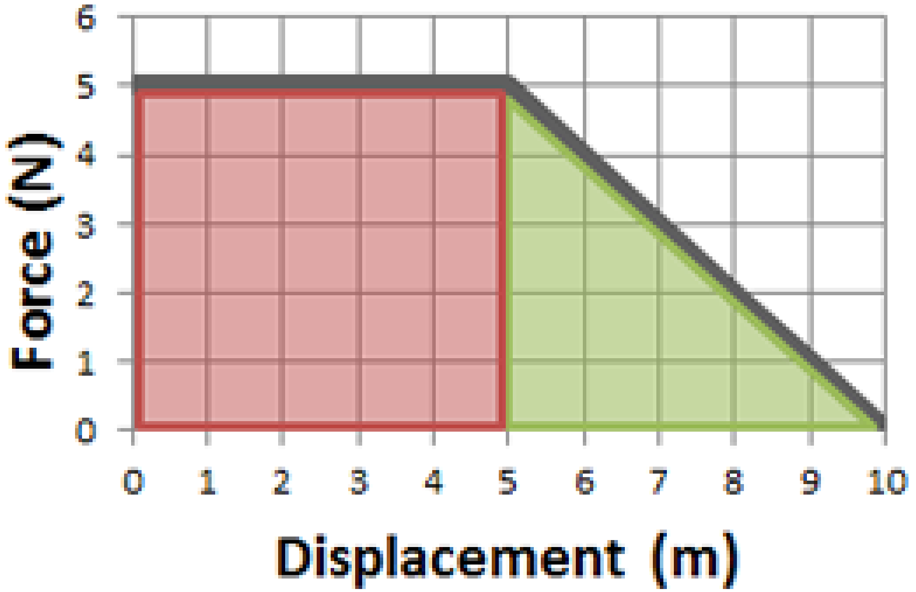
A block is pulled across a table with a constant force of 5N over a displacement of 5m, then tapers off over 5m.

$$W = Area_{rectangle} + Area_{Triangle}$$

$$W = l * w + 1/2bh$$

$$W = (5m)(5N) + ½(5m)(5N)$$

$$W = 37.5J$$



AP Physics I

Energy -

Plan

- Review Work & Homework…or not.
- New homework…more basic.
- Intro to:
  - Kinetic Energy
  - Gravitational Potential Energy
  - Elastic Potential Energy (springs, Hooke’s law)

Review of Work

$W = Fd\cos\theta$

- Work can be negative but sign is decided by $\cos\theta$
- Use magnitude of F & d in equation so always positive.
- Do not have to break into components because equation takes care of it for us.
- Still need to make sure using right trig function!

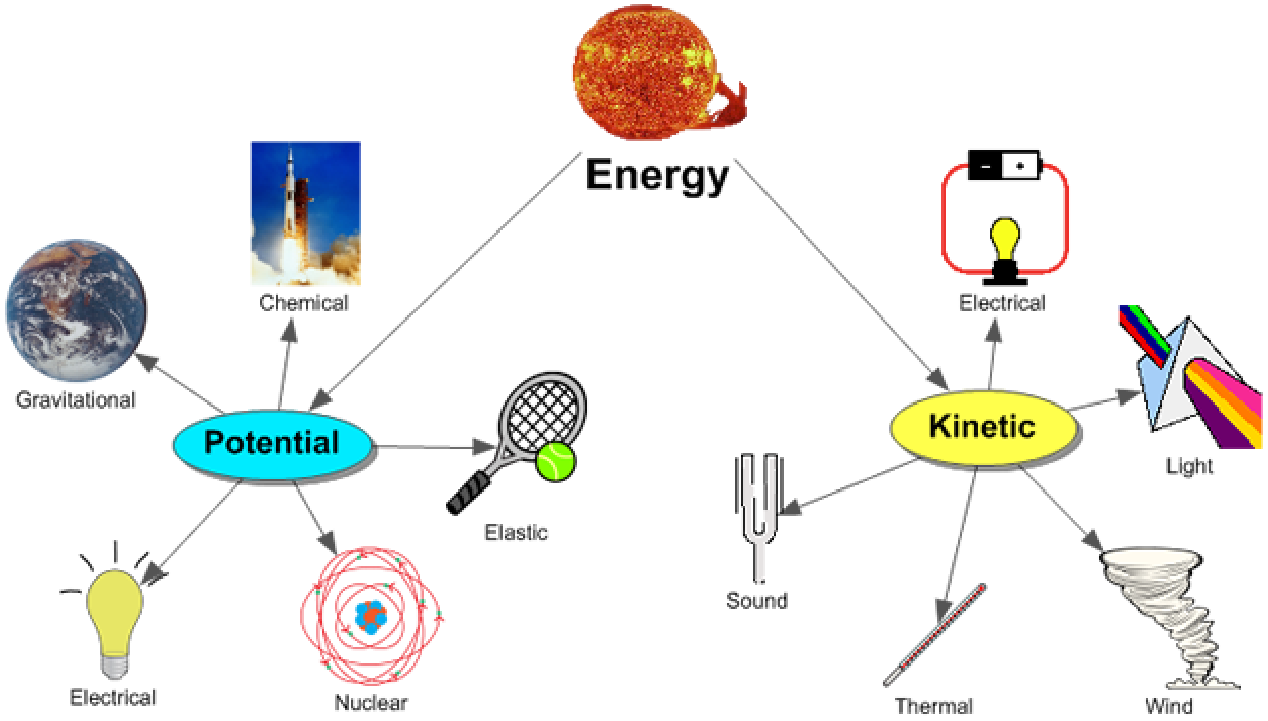
Review Problem Example

Shopping cart is being pushed with a force of 6.9 N left at an angle of 59^0 for 7.0m in a horizontal distance. What is the work done by the shopper on the shopping cart?

$$W = Fd\cos\Theta = (6.9N)(7m)(\cos(90-59)) = 41J$$

Energy

- In Physics, energy is the ability or capacity to do work.
- Since work is the process of moving an object,
- Energy is the ability or capacity to move an object.
- Two main types: kinetic(motion) or potential (stored).



Kinetic Energy

$$KE = \frac{1}{2}mv^2$$

$$KE = \frac{kg \ * m^2}{s^2} = N * m = J$$

Gravitational Potential Energy

- Potential energy is energy an object possesses due to its position or condition.
- Gravitational potential energy, then, is the energy an object possesses because of its position in a gravitational field (height).

$$W = Fd = (mg)(h) = mgh$$

Example

- We have a 10 kg box on the floor. To do the work to lift the box one meter off the floor, we need to overcome the force of gravity on the box (its weight) over a distance of one meter.
- Therefore, the work we do on the box can be obtained from:

$$W = Fd = mgh$$

$$W = Fd = (10kg)(9.81m/s^2)(1m) = 98.1J$$

What does that mean?

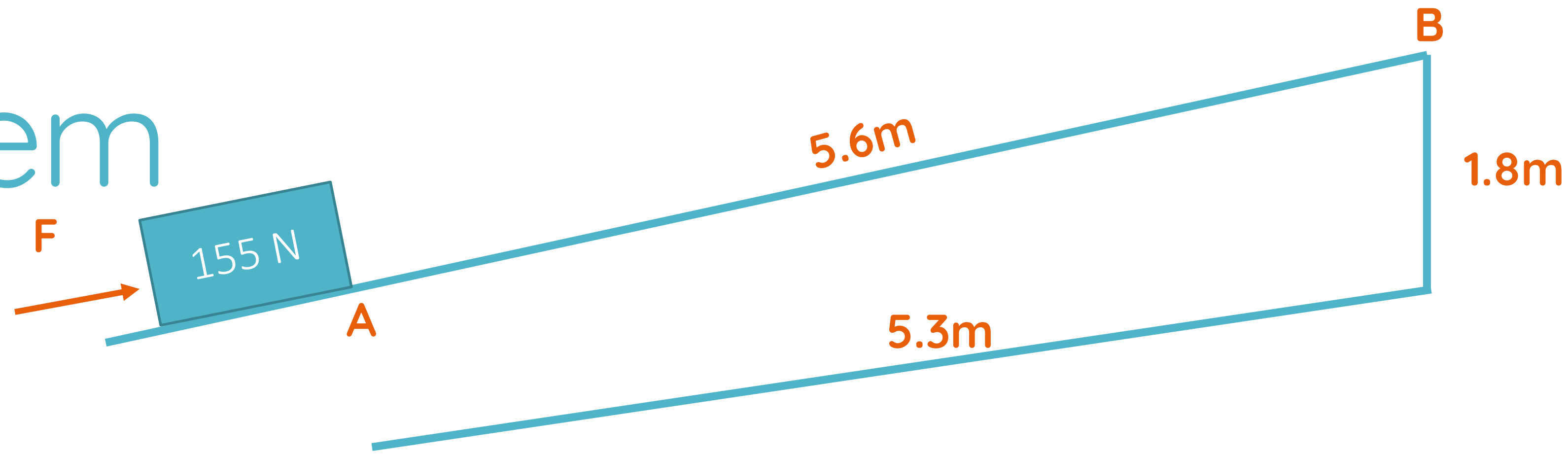
- To raise the box to a height of 1m, we must do 98.1 Joules of work.
- Work done in lifting is equal to change in potential energy of the box.
- Gravitational potential energy of box is equal to 98.1J.

$$\Delta PE = mg\Delta h$$

- Also called

$$\Delta U_g = mg\Delta h$$

Class Problem

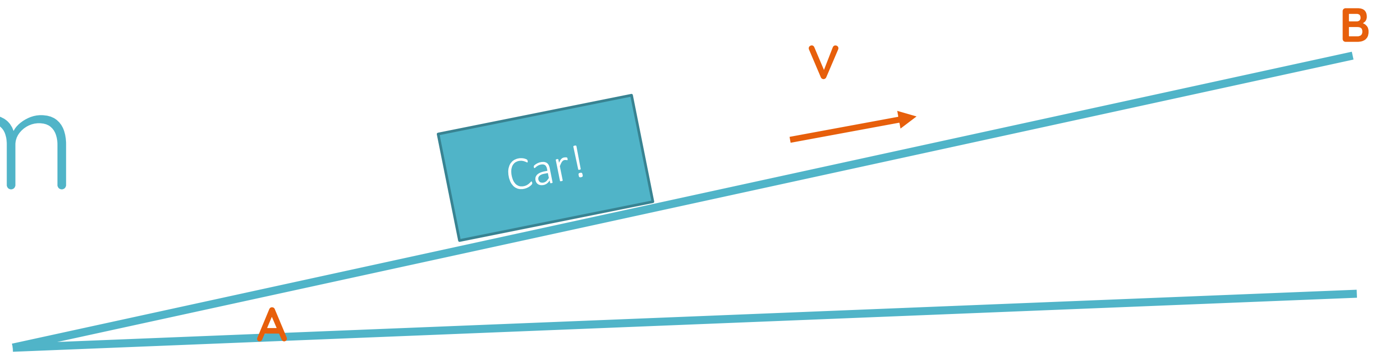


Applied force F causes the box to slide from point A to point B

What is the total amount of gravitational potential energy gained by the box?

$$\Delta PE = mg\Delta h = (155N)(1.8m) = 279J$$

Class Problem



Car travels at constant speed v up a hill from point A to point B as shown. As the car travels from A to B, its gravitational potential energy:

A) increases and its kinetic energy decreases

B) increases and its kinetic energy remains the same

C) remains the same and its kinetic energy decreases

D) remains the same and its kinetic energy remains the same

Answer: B. Car's height above ground increases so GPE increases and velocity remains constant so KE stays same

Springs & Hooke's Law

- Let's look at force applied by a spring.
- The more you stretch a spring, the greater the force of the spring… similarly, the more you compress a spring, the greater the force.
- Can be modeled as a linear relationship, where force applied by the spring is equal to a constant times displacement of the spring.

$$|\overline{F}| = k|\bar{x}|$$

Springs & Hooke's Law

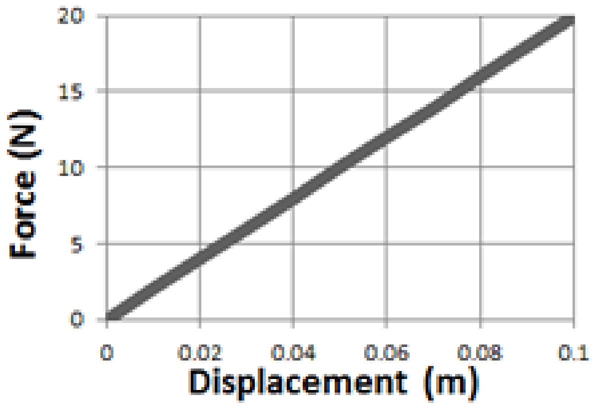
$$|\overline{F_s}| = k|\bar{x}|$$

- F_s is the force of the spring in newtons,
- x is the displacement of the spring from its equilibrium (or rest) position, in meters, and
- k is the spring constant which tells you how stiff or powerful a spring is, in Newtons per meter.
- The larger the spring constant, k, the more force the spring applies per amount of displacement.

Finding the Spring Constant

Find k by making a graph of force from a spring on the y-axis, and displacement of the spring from its equilibrium on the x-axis.

The slope of the graph will give you k.



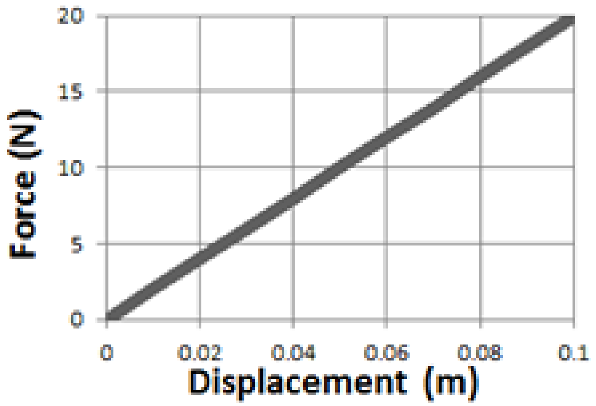
$$k = \text{slope} = \frac{rise}{run} = \frac{\Delta F}{\Delta x} = \frac{20N - 0N}{0.1m - 0m} = 200 \text{ N/m}$$

Work must have been done to compress/stretch spring – can find that by taking the area.

The work to displace the spring by 0.1 is:

Finding Work Done

$$k = \text{slope} = \frac{rise}{run} = \frac{\Delta F}{\Delta x} = \frac{20N - 0N}{0.1m - 0m} = 200 \text{ N/m}$$



Work must have been done to compress/stretch spring – can find that by taking the area.

The work to displace the spring by 0.1 is:

$$W = \text{Area}$$

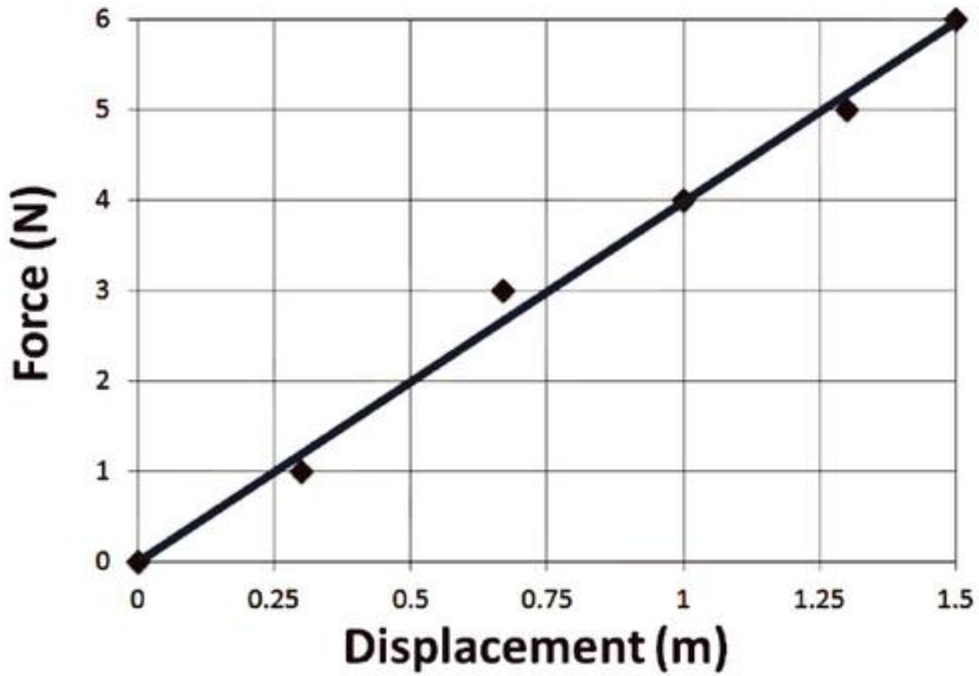
$$W = 1/2bh$$

$$W = 1/2(0.1\text{m})(20\text{N}) = 1\text{J}$$

Class Problem

In an experiment, a student applied various forces to a spring and measured the spring's correspond le.

Plot force vs line.
Calculate sp



$$k = Slope = \frac{rise}{run} = \frac{\Delta F}{\Delta x} = \frac{6N - 0N}{1.5m - 0m} = 4\,{}^{N}\!/_{m}$$

Force (newtons)	Elongation (meters)
0	0
1.0	0.30
3.0	0.67
4.0	1.00
5.0	1.30
6.0	1.50

Elastic Potential Energy

- Energy stored in an object due to temporary deformation of an object. Spring!
- An object at the end of a compressed spring, for example, has elastic potential energy.
- When the spring is released, the elastic potential energy of the spring will do work on the object, moving the object and transferring the energy of the spring into kinetic energy of the object.
- Other examples of elastic potential energy include tennis rackets, rubber bands, bows (as in bows and arrows), trampolines, bouncy balls, and even pole-vaulting poles.

Formula Elastic Potential Energy

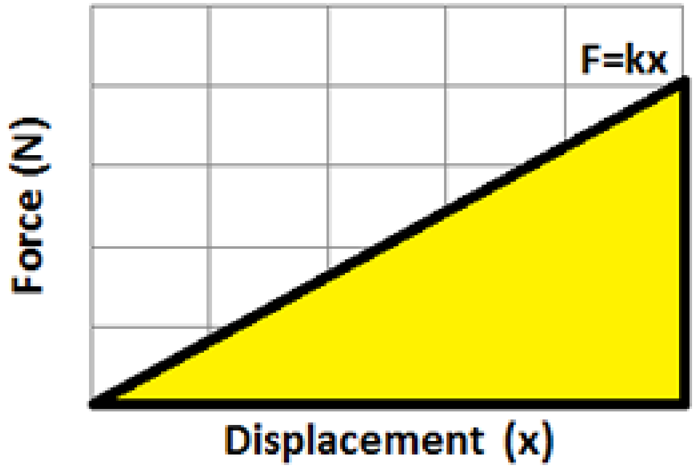
$$PE = Fd = \frac{1}{2}kx^2$$

- k is the spring constant in N/m
- x is the displacement from equilibrium position
- Sometimes called the rest position.

- k – how much a spring resists compression. How much force does it take to compress it?

Finding Work

Just as we talked about in Hooke's Law – can find work done in compressing or stretching string by taking the area.



Class Problem

A spring with a spring constant of 4.0N/m is compressed by a 1.2N force. What is total elastic potential energy stored in spring?

Find x from Hooke's Law.

$$|\bar{F_s}| = k|\bar{x}|$$

$$|\bar{x}| = \frac{|\bar{F_s}|}{k} = \frac{1.2N}{4N/m} = 0.3m$$

$$PE = \frac{1}{2}\left(\frac{4.0N}{m}\right)(0.3m)^2 = 0.18J$$