Potential Energy

We have seen that an object in motion has kinetic energy. Objects may also have other forms of energy. For example, when you do work to wind the spring of a toy car, you give the spring a form of energy called **potential energy**. It is called potential energy because it has the **potential** to do work (when the spring unwinds, it will cause the car to move). For this reason, potential energy is often thought of as stored energy.

Gravitational Potential Energy

To lift an object of mass *m* to a height *h* requires you to do work. The amount of work required is given by:

$$\begin{aligned} W &= F \cdot d \\ &= F_g \cdot h \\ &= mgh \end{aligned}$$

If the object is released, it will fall. As it falls, it accelerates, gaining velocity and kinetic energy, and thereby the ability to do work. Because the object at height *h* is capable of doing work if it is released, we say it has **gravitational potential energy** due to its position.

Neat the earth's surface an object's gravitational potential energy is given by:

$$\boxed{E_g = mgh}$$

where h is the height above the reference level (usually the earth's surface).

Note: When solving problems involving gravitational potential energy, you must choose a reference level and stick with it throughout the problem. You can choose any level, but a wise choice will simplify your efforts.

Example 1
How much potential energy does a $7.5\ kg$ ceiling fan have with respect to the floor when it is $3.0\ m$ above it?

Example 2
A 500 kg pile driver is dropped from a height of 3.0 m onto a piling in the ground. The impact drives the piling 1.0 cm deeper into the ground. What was the average force exerted on the piling by the pile driver?

Elastic Potential Energy

Just as we can store energy by raising a mass in a gravitational field, we can store energy in a spring by stretching or compressing it. We call this **elastic potential energy**. To determine its value, we must determine how much work is needed to stretch or compress a spring through a displacement x.

$$W = F \cdot d$$

It can be shown experimentally that the amount of deformation (x) of an elastic object is directly proportional to the amount of force used to deform it.

$$F = k \cdot x \qquad \text{(Hooke's Law)}$$

Where k is a constant (called the spring constant) that has a unique value for each spring.

When stretching or compressing a spring, the force varies linearly with the amount of deformation from 0 to kx. Therefore, the average force exerted on the spring to stretch or compress it a distance x will be given by

$$\overline{F} = \frac{1}{2}kx$$

Thus, the amount of work done to deform a spring through a displacement x is given by:

$$
\begin{aligned}
W &= F \cdot d \\
&= \left(\frac{1}{2}kx\right) \cdot (x) \\
&= \frac{1}{2}kx^2
\end{aligned}
$$

We define the elastic potential energy of a deformed spring as:

$$\boxed{E_s = \frac{1}{2}kx^2}$$

Where k is the spring constant (in N/m) and x is the amount of deformation of the spring from its rest position.

Example 3
What is the elastic potential energy stored in a spring whose spring constant is $160\ N/m$ when it is compressed $8.0\ cm$?

Example 4
A $1550\ kg$ Pontiac Grand Prix is supported by four coil springs each with a spring constant of $70000\ N/m$. (a) By how much are the springs compressed beyond their normal length? (b) How much energy is stored in the springs?

Homework
Energy Worksheet #3

Energy Worksheet #3

1. How much potential energy with respect to ground level dos a $10.0\ kg$ lead weight have when it is $2.0\ m$ above the surface of the ground? ($196\ J$)

2. A $0.302\ kg$ coffee mug rests on a table top $0.740\ m$ above the floor.
   a. What is the potential energy of the mug with respect to the floor? ($2.19\ J$)
   b. What is its potential energy with respect to the counter top $1.10\ m$ above the floor? ($-1.07\ J$)

3. Relative to the ground, what is the gravitational potential energy of a $55.0\ kg$ person who is at the top of the Sears Tower, a height of $443\ m$ above the ground? ($239000\ J$)

4. A $0.15\ kg$ ball is thrown $9.0\ m$ straight up.
   a. Find the work done by the gravitational force. ($-13.23\ J$)
   b. What is the change in the ball's gravitational potential energy? ($13.23\ J$)

5. A pole-vaulter just clears the bar at $5.80\ m$ and falls back to the ground. The change in the pole-vaulter's potential energy is $-3700\ J$. What is his weight? ($638\ N$)

6. A $75.0\ kg$ skier rides a $2830\ m$ long lift to the top of a mountain. The lift makes an angle of $14.6°$ with the horizontal. What is the change in the skier's gravitational potential energy? ($524317\ J$)

7. What force is necessary to stretch a spring whose force constant is $120\ N/m$ by an amount of $30\ cm$? ($36\ N$)

8. A spring in a pogo stick is compressed $12\ cm$ when a $40\ kg$ boy stands on the stick. What is the spring constant for the pogo stick's spring? ($3300\ N/m$)

9. A spring compressed by $0.080\ m$ stores $150\ J$ of elastic potential energy. What is the value of the spring constant *k*? ($47000\ N/m$)

10. What is the spring constant of a Hooke's Law spring if the extension of the spring is $0.15\ m$ when $0.72\ J$ of potential energy is stored in it? ($64\ N/m$)

11. How much would a spring scale with a spring constant of $120\ N/m$ stretch, if it had $3.75\ J$ of work done on it? ($0.25\ m$)

12. An archer pulls the bowstring back for a distance of $0.470\ m$ before releasing the arrow. The bow and string act like a spring whose spring constant is $425\ N/m$. What is the elastic potential energy of the drawn bow? ($46.9\ J$)

13. A spring hangs vertically from the ceiling. The spring extends an amount x when a mass m is hung from its free end. Find an expression for the energy stored in the spring in terms of m, the acceleration of gravity g, and x. $\left(E_s = \frac{1}{2}mgx\right)$

YOU MIGHT BE A PHYSICS MAJOR...

- if you have no life - and you can PROVE it mathematically.
- if you enjoy pain.
- if you know vector calculus but you can't remember how to do long division.
- if you chuckle whenever anyone says "centrifugal force."
- if you've actually used every single function on your graphing calculator.
- if when you look in a mirror, you see a physics major.
- if it is sunny and 70 degrees outside, and you are working on a computer.
- if you always do homework on Friday and Saturday nights.
- if you know how to integrate a chicken and can take the derivative of water.
- if you think in "math."
- if you've calculated that the World Series actually diverges.
- if you hesitate to look at something because you don't want to break down its wave function.
- if you have a pet named after a scientist.
- if you laugh at jokes about mathematicians.
- if the Humane society has you arrested because you actually performed the Schrodinger's Cat experiment.
- if you can't remember what's behind the door in the science building which says "Exit."
- if you have to bring a jacket with you, in the middle of summer, because there's a wind-chill factor in the lab.
- if you are completely addicted to PhysLink.com.
- if you avoid doing anything because you don't want to contribute to the eventual heat-death of the universe.
- if you consider ANY non-science course "easy."
- if when your professor asks you where your homework is, you claim to have accidentally determined its momentum so precisely, that according to Heisenberg it could be anywhere in the universe.
- if the "fun" center of your brain has deteriorated from lack of use.
- if you'll assume that a "horse" is a "sphere" in order to make the math easier.
- if you understood more than five of these indicators.
- if you make a hard copy of this list, and post it on your door.

If these indicators apply to you, there is good reason to suspect that you might be classified as a physics major.