Potential Energy

Ck12 Science

Say Thanks to the Authors
Click http://www.ck12.org/saythanks
(No sign in required)

AUTHOR
Ck12 Science

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-content, web-based collaborative model termed the **FlexBook®**, CK-12 intends to pioneer the generation and distribution of high-quality educational content that will serve both as core text as well as provide an adaptive environment for learning, powered through the **FlexBook Platform®**.

Printed: March 24, 2014

flexbook
next generation textbooks

CHAPTER 1 Potential Energy

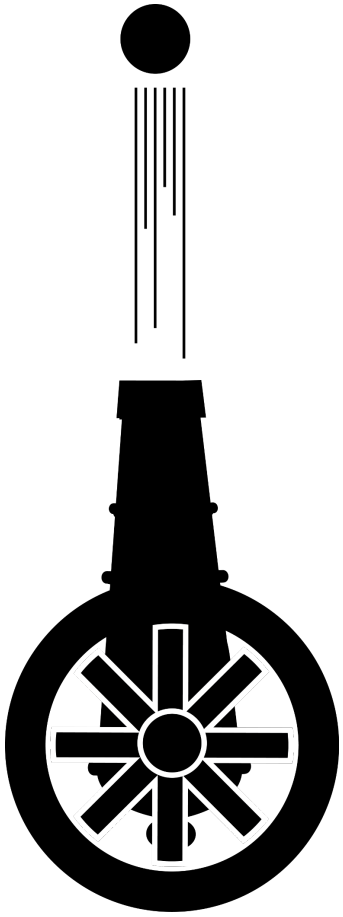
- Define potential energy.
- Solve problems involving gravitational potential energy.
- Solve problems involving the conversion of potential energy to kinetic energy and vice versa.

Shooting an arrow from a bow requires work done on the bow by the shooter's arm to bend the bow and thus produce potential energy. The release of the bow converts the potential energy of the bent bow into the kinetic energy of the flying arrow.

Potential Energy

When an object is held above the earth, it has the ability to make matter move because all you have to do is let go of the object and it will fall of its own accord. Since energy is defined as the ability to make matter move, this object has energy. This type of energy is stored energy and is called **potential energy.** An object held in a stretched rubber band also contains this stored energy. Specifically, a rubber band (and the bow pictured above) has *elastic* potential energy. If the stretched rubber band is released, the object will move. If you hold two positive charges near each other, their *electromagnetic* potential energy pushes them apart when you let go. Potential energy is stored in chemical bonds (*chemical*). When these bonds are broken, the excess energy is seen as molecular motion and heat.

If a cannon ball is fired straight up into the air, it begins with a high kinetic energy. As the cannon ball rises, it slows down due to the force of gravity pulling it toward the earth. As the ball rises, its gravitational potential energy is increasing and its kinetic energy is decreasing. When the cannon ball reaches the top of its arc, its kinetic energy is zero and its potential energy is at the maximum. As gravity continues to pull the cannon ball toward the earth, the ball will fall downwards, causing its height to decrease and its speed to increase. The ball's potential energy decreases and its kinetic energy increases. When the ball returns to its original height, its kinetic energy will be the same as when it started upward.



When work is done on an object, the work may be converted into either kinetic or potential energy. Work resulting in motion is caused when the work is converted into kinetic energy, while work resulting in a change of position is caused by a conversion into potential energy. Work is also spent overcoming friction and that work would be converted into heat, but we will consider primarily frictionless systems.

If we consider the potential energy of a bent stick or a stretched rubber band, the potential energy can be calculated by multiplying the force exerted by the stick or rubber band by the distance over which the force will be exerted. The formula for calculating this potential energy looks exactly like the formula for calculating work done: $W = Fd$. The only difference is that work is calculated when the object actually moves and potential energy is calculated when the system is still at rest, before any motion actually occurs.

In the case of gravitational potential energy, the force exerted by the object is its weight and the distance it can travel is its height above the earth. Since the weight of an object is calculated by $W = mg$, then gravitational potential energy can be calculated by $PE = mgh$, where m is the mass of the object, g is the acceleration due to gravity, and h is the height the object will fall.

Example Problem: A 3.00 kg object is lifted from the floor and placed on a shelf that is 2.50 m above the floor.

(a) What was the work done in lifting the object?

(b) What is the gravitational potential energy of the object sitting on the shelf?

(c) If the object falls off the shelf and falls to the floor in the absence of air resistance, what will its velocity be when it hits the floor?

Solution: weight of the object $= mg = (3.00\ kg)(9.80\ m/s^2) = 29.4\ N$

(a) $W = Fd = (29.4\ N)(2.50\ m) = 73.5\ J$

(b) $PE = mgh = (3.00\ kg)(9.80\ m/s^2)(2.50\ m) = 73.5\ J$

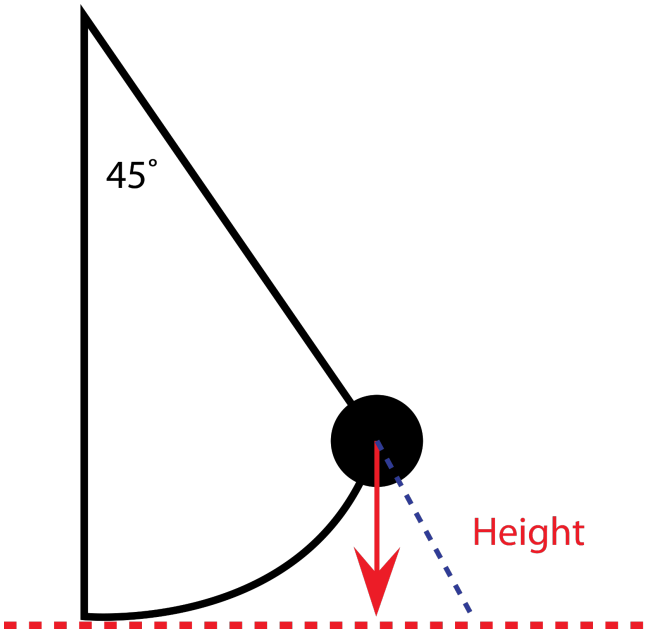
(c) $KE = PE$ so $\frac{1}{2}\ mv^2 = 73.5\ J$

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{(2)(73.5\ J)}{3.00\ kg}} = 7.00\ m/s$$

Example Problem: A pendulum is constructed from a 7.58 kg bowling ball hanging on a 3.00 m long rope. The ball is pulled back until the rope makes an angle of 45° with the vertical.

(a) What is the potential energy of the ball?

(b) If the ball is released, how fast will it be traveling at the bottom of its arc?



Solution: You can use trigonometry to find the vertical height of the ball in the pulled back position. This vertical height is found to be 0.877 m.

$PE = mgh = (7.58\ kg)(9.80\ m/s^2)(0.877\ m) = 65.1\ J$

When the ball is released, the PE will be converted into KE as the ball swings through the arc.

$KE = \frac{1}{2}\ mv^2 = 65.1\ J$

$$v = \sqrt{\frac{(2)(65.1\ kg \cdot m^2/s^2)}{7.58\ kg}} = 4.14\ m/s$$

Summary

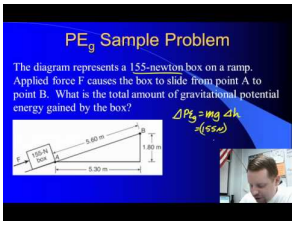
- Stored energy is called potential energy.
- Energy may be stored by holding an object elevated in a gravitational field or by holding it while a force is attempting to move it.

- Potential energy may be converted to kinetic energy.
- The formula for gravitational potential energy is $PE = mgh$.
- In the absence of friction or bending, work done on an object must become either potential energy or kinetic energy or both.

Practice

The following video discusses types of energy. Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=nC6tT1wkXEc



MEDIA

Click image to the left for more content.

1. What is the definition of energy?
2. Name two types of potential energy.
3. How is energy transferred from one object to another?

Potential and kinetic energy practice problems with solutions:

http://www.physicsclassroom.com/Class/energy/U5L2bc.cfm

Review

1. A 90.0 kg man climbs hand over hand up a rope to a height of 9.47 m. How much potential energy does he have at the top?
2. A 50.0 kg shell was fired from a cannon at earth's surface to a maximum height of 400. m. What is the potential energy at maximum height?
3. If the shell in problem #2 then fell to a height of 100. m, what was the loss of PE?
4. A person weighing 645 N climbs up a ladder to a height of 4.55 m.
   (a) What work does the person do?
   (b) What is the increase in gravitational potential energy?
   (c) Where does the energy come from to cause this increase in PE?

- **potential energy:** Otherwise known as stored energy, is the ability of a system to do work due to its position or internal structure. For example, gravitational potential energy is a stored energy determined by an object's position in a gravitational field while elastic potential energy is the energy stored in a spring.

References

1. Image copyright Skynavin, 2013. http://www.shutterstock.com . Used under license from Shutterstock.com
2. Image copyright Tribalium, 2013; modified by CK-12 Foundation - Samantha Bacic. http://www.shutterstock.com . Used under license from Shutterstock.com
3. CK-12 Foundation - Samantha Bacic. . CC-BY-NC-SA 3.0