Energy – Internal and External Forces*

Richard Baldwin

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Abstract

This module explains internal and external forces in a format that is accessible to blind students.

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2 Preface

2.1 General

This module is part of a collection (see http://cnx.org/content/col11294/latest/ [1]) of modules designed to make physics concepts accessible to blind students. The collection is intended to supplement but not to replace the textbook in an introductory course in high school or college physics.

This module explains internal and external forces in a format that is accessible to blind students.

2.2 Prerequisites

In addition to an Internet connection and a browser, you will need the following tools (as a minimum) to work through the exercises in these modules:

- A graph board for plotting graphs and vector diagrams (http://www.youtube.com/watch?v=c8plj9UsJbg [2]).

*Version 1.2: Oct 8, 2012 1:52 pm -0500

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[1] http://cnx.org/content/col11294/latest/

[2] http://www.youtube.com/watch?v=c8plj9UsJbg

- A protractor for measuring angles (http://www.youtube.com/watch?v=v-F06HgiUpw [3]).
- An audio screen reader that is compatible with your operating system, such as the NonVisual Desktop Access program (NVDA), which is freely available at http://www.nvda-project.org/ [4] .
- A refreshable Braille display capable of providing a line by line tactile output of information displayed on the computer monitor (http://www.userite.com/ecampus/lesson1/tools.php [5]).
- A device to create Braille labels. Will be used to label graphs constructed on the graph board.

The minimum prerequisites for understanding the material in these modules include:

- A good understanding of algebra.
- An understanding of the use of a graph board for plotting graphs and vector diagrams (http://www.youtube.com/watch? [6]).
- An understanding of the use of a protractor for measuring angles (http://www.youtube.com/watch?v=v-F06HgiUpw [7]).
- A basic understanding of the use of sine, cosine, and tangent from trigonometry (http://www.clarku.edu/∼djoyce/trig/ [8]).
- An introductory understanding of JavaScript programming (http://www.dickbaldwin.com/tocjscript1.htm [9] and http://www.w3schools.com/js/default.asp [10]).
- An understanding of all of the material covered in the earlier modules in this collection.

2.3 Supplemental material

I recommend that you also study the other lessons in my extensive collection of online programming tutorials. You will find a consolidated index at www.DickBaldwin.com [11] .

3 Discussion

Work

You learned in an earlier module that work is done on an object when that object is displaced by a force. You further learned that the amount of work done is proportional to the product of the force, the displacement distance, and the cosine of the angle between them.

Mechanical energy

You also learned in an earlier module that mechanical energy is the energy that is possessed by an object due to its motion or due to its position *(where position includes the deformation, stretching, compressing, etc., involved in elastic potential energy)* .

Mechanical energy can be either kinetic energy resulting from motion or potential energy resulting from the position of the object.

Two categories of force

When speaking of work and energy, we can categorize force into two categories:

- internal or conservative force
- external or non-conservative force

[3] http://www.youtube.com/watch?v=v-F06HgiUpw
[4] http://www.nvda-project.org/
[5] http://www.userite.com/ecampus/lesson1/tools.php
[6] http://www.youtube.com/watch?v=c8plj9UsJbg
[7] http://www.youtube.com/watch?v=v-F06HgiUpw
[8] http://www.clarku.edu/∼djoyce/trig/
[9] http://www.dickbaldwin.com/tocjscript1.htm
[10] http://www.w3schools.com/js/default.asp
[11] http://www.dickbaldwin.com/toc.htm

In theory, the distinction between the two categories is not complicated. Work done on an object solely by internal forces cannot change the total mechanical energy possessed by an object. Work done on an object by external forces can change the total mechanical energy possessed by an object.

Internal forces

Internal forces are forces that can act on an object without physically touching the object. Examples of internal forces include:

- the force of gravity
- electrical forces
- magnetic forces
- spring forces

These forces cannot change the total mechanical energy possessed by an object, but can transform that energy between potential energy and kinetic energy.

External forces

Examples of external forces include:

- applied force
- normal force
- tension force
- friction force
- air resistance force

When work is done on an object by external forces, the total mechanical energy, consisting of kinetic energy plus potential energy, will change. The work can be positive, in which case the total mechanical energy will increase. The work can be negative, in which case the total mechanical energy will decrease. The change in mechanical energy will be equal to the net work that is done on the object.

A Super Ball example

Assume that a Super Ball *(a toy manufactured by Wham-O that bounces with great vigor)* is at rest on a table. The ball has a certain amount of potential energy due to its position relative to the floor. While at rest, however, it has no kinetic energy. The total mechanical energy possessed by the ball is the potential energy due to gravity.

The ball falls

Assume that the ball is dangerously close to the edge of the table and the family cat accidently tips the ball off the table.

As the ball falls towards the floor, it will be losing potential energy because its height above the floor will be decreasing. At the same time, it will be gaining kinetic energy because its speed will be increasing.

A transfer of energy

Assuming that we can neglect air resistance and that no forces other than the force of gravity are acting on the ball, during its fall, it will be subjected only to the *internal* force of gravity. During that time interval, its total mechanical energy cannot change. The loss in potential energy will be replaced by an increase in kinetic energy and the total mechanical energy possessed by the ball will remain constant.

An external force is applied

Suddenly the ball reaches the floor. At that instant, an *external* upward force will be applied to the ball by the normal force exerted by the floor. There will be a change in the total mechanical energy possessed by the ball, if for no reason other than the fact that some of the energy is converted into sound wave energy. Both the kinetic energy and the gravitational potential energy will go to zero for a very short period of time.

Negative work

The work done on the ball by the floor will be negative because the force will be in the opposite direction of the direction of the displacement. Thus, the total mechanical energy will be decreased.

Conversion into elastic potential energy

However, some of the mechanical energy will probably be converted into elastic potential energy as the ball is compressed.

Shortly thereafter, that elastic potential energy will be converted into kinetic energy as the ball expands causing it to bounce up.

Another trip involving only internal forces

On the way up from the bounce, the potential energy due to gravity will be increasing and the kinetic energy will be decreasing until the ball reaches the top of the bounce.

For an instant, the kinetic energy will be zero and the gravitational potential energy will be at its maximum. Then the ball will begin its trip back toward the floor, gaining kinetic energy and losing potential energy along the way.

Application of another external force

Then the ball will strike the floor again, and the process will repeat. Each time the ball strikes the floor, some of the total mechanical energy will be lost, having been converted into some other form of energy such as thermal energy, sound wave energy, etc.

All of the potential energy is expended

Eventually, an amount of energy equal to the original potential energy will have been converted into those other forms of energy and the ball will come to rest on floor. However, because of the design of the Super Ball, many cycles of the process may be required for the ball to come to rest.

An aside – a ball of Play Doh

Consider what would happen if instead of being a Super Ball, the toy were a ball of Play Doh *(a toy manufactured by Hasbro that doesn't bounce very well)* . The ball of Play Doh would probably only make one trip from the tabletop to the floor.

On the way down, the ball of Play Doh would exchange potential energy for kinetic energy. When it hits the floor, all of the kinetic energy would probably be expended by converting it to heat energy, sound energy, etc., and by deforming the ball of Play Doh beyond its elastic limit. (Play Doh has a very low elastic limit, if any.)

Not done with the Super Ball yet

Now let's get back to the case of the Super Ball. Keep in mind that the total mechanical energy possessed by the ball when it comes to rest on the floor is not zero, because it still feels an attraction due to the force of gravity. Thus, it still possesses gravitational potential energy.

If all of this has been happening in a second-story loft, and the cat comes along again and causes the ball to roll off the edge of the loft floor, a process similar to that described above will occur all over again involving the ball and the floor below the loft.

Another phenomena

There is another phenomena that would probably occur with the Super Ball, but which would be visible only through the use of high-speed photography or other sensitive technology.

Oscillations

The impact with the floor would probably cause the ball to go into spring-like oscillations. By this I mean that it would be compressed by the impact with the floor. When it expands, (in addition to causing it to bounce upward), the ball would probably over-expand or stretch and gain elastic potential energy in the stretched configuration.

Energy conversion

During this process, the potential energy due to compression would be converted to kinetic energy as the molecules in the ball fly away from one another, and then be converted into potential energy again as the molecules fly too far away from one another (stretch).

Compress again

Then the ball would compress again and the process of stretching and compressing would continue until the elastic potential energy stored by the compression of the impact with the floor is expended by transforming it into heat energy, sound energy, etc.

Between impacts with the floor, this process would be occurring in addition to the activity involving gravitational potential energy.

A Slinky toy

A Slinky is a toy that was patented by R.T. James in 1946 and is currently manufactured by James industries.

The original Slinky toy was a coil spring made of spring steel with a diameter of about two inches. I can still remember the first time I saw one "crawling" down a flight of stairs, and I can remember the student that brought it to elementary school to show it off. (Slinky toys are also made of plastic these days and are made with different diameters.)

If you hold one end of a Slinky toy and allow the other end to fall toward the floor, the type of oscillations described above can easily be observed by a sighted person. The bottom end of the spring goes up and down rather slowly, exchanging elastic potential energy for kinetic energy and back again during each cycle.

Probably discernable by a blind student

If a blind student were to do this with a Slinky toy, particularly with one of the older and heavier versions made of spring steel, the student would probably be able to feel the oscillations as the bottom end of the spring goes up and down.

The blind student could also probably experience the phenomena by gently touching one side of the spring and feeling the individual coils moving up and down as the spring stretches and compresses.

Conservative versus non-conservative forces

Internal forces are often referred to as *conservative* forces because they are incapable of changing the total mechanical energy possessed by an object. In other words, the mechanical energy possessed by an object is conserved when the object is acted upon by internal forces.

External forces, on the other hand, are often referred to as *non-conservative* forces for exactly the opposite reason. The mechanical energy possessed by an object is not conserved when the object is acted upon by external forces. In particular, the mechanical energy possessed by the object will either increase or decrease by the net positive or negative work done on the object by external forces.

External forces always occur

While discussing physics concepts, we often like to assume conditions such as a friction-free surface, etc. However, there is no such thing as a friction-free surface. If there were, we could build the ultimate perpetual-motion machine and solve the world's energy problems forever.

A skier on a friction-free surface

If we speak of a skier gliding down a hill on a friction free surface, we can talk about the skier losing potential energy and gaining kinetic energy on the way down. Neglecting air resistance and other external forces, we can say that there is no change in the mechanical energy possessed by the skier on the trip down the hill. The skier's potential energy is converted to kinetic energy.

Bad for the ski business

But what happens when the skier reaches the bottom of the hill? Some external force must be applied to the skier to cause the skier's velocity to change. (Remember, the velocity of an object can only be changed by the application of a force.)

Without the application of that external force, the skier would continue moving with the same velocity and disappear over the horizon. It would be bad for the ski business if every skier disappeared after only one trip down the ski slope.

A falling object

It has been said that a fall doesn't hurt you. It's the sudden stop (negative acceleration) at the end of the fall that hurts. We can discuss the concept of only internal forces acting on an object while it is falling by neglecting air resistance and other external forces.

Eventually, however, that falling object must reach the surface of the earth, the floor, the table top, or some other surface that represents the zero reference for gravitational potential energy. When that happens, an external force must occur to change the object's velocity and change the mechanical energy possessed by the object.

4 Resources

I will publish a module containing consolidated links to resources on my Connexions web page and will update and add to the list as additional modules in this collection are published.

5 Miscellaneous

This section contains a variety of miscellaneous information.

NOTE: **Housekeeping material**

- Module name: Energy – Internal and External Forces for Blind Students
- File: Phy1210.htm
- Keywords:
  - physics
  - accessible
  - accessibility
  - blind
  - graph board
  - protractor
  - screen reader
  - refreshable Braille display
  - JavaScript
  - trigonometry
  - potential energy
  - work
  - gravitational potential energy
  - elastic potential energy
  - kinetic energy
  - mechanical energy
  - total mechanical energy
  - power
  - watt
  - internal force
  - conservative force
  - external force
  - non-conservative force

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Affiliation : I am a professor of Computer Information Technology at Austin Community College in Austin, TX.

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