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Potential Energy and Conservation of Energy

Module Overview

Acknowledgments

This presentation is based on and includes content derived from the following OER resource:

University Physics Volume 1

An OpenStax book used for this course may be downloaded for free at:
https://openstax.org/details/books/university-physics-volume-1

Potential Energy Basics

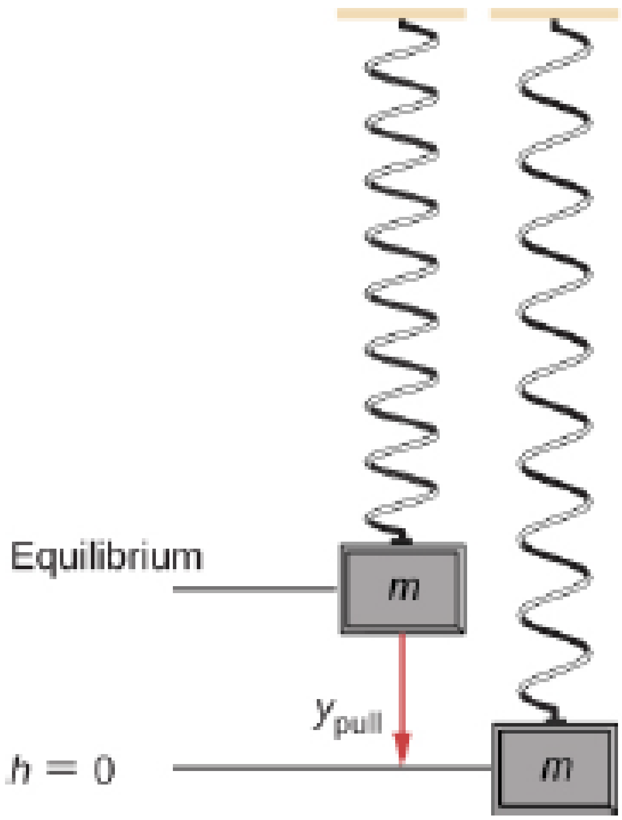
Potential energy, U, is a type of energy that quantifies the ability of a system to do work. **Potential energy difference**, $\Delta U_{AB} = U_B - U_A$, is equal to the negative of the work done by the object, $\Delta U_{AB} = -W_{AB}$. To make definite statements about the potential energy of a system, we choose an arbitrary constant potential energy, $U(\vec{\mathbf{r}}_0)$, at position $\vec{\mathbf{r}}_0$. This constant is often chosen to be zero. In the absence of friction and air resistance, the change in kinetic energy of a system is equal to the change in its potential energy, $\Delta K_{AB} = \Delta U_{AB}$.

The potential energies of a collection of particles is the negative of the work done by external forces. Change in potential energy depends only on the positions of each particle and parameters like mass or the spring constant.

Gravitational and Elastic Potential Energy

Gravitational potential energy is the negative of the work done by gravity, $U(y) = mgy + \text{constant}$. Elastic potential energy is built up when work is done to displace a spring from its equilibrium and is given by $U(x) = \frac{1}{2}kx^2 + \text{constant}$.

The constants are often both chosen such that $U = 0$ is the lowest possible potential.



(University Physics Volume 1. OpenStax. Fig. 8.5)

Conservative Forces, Part 1

A **conservative force** is one that preserves the total–kinetic plus potential–energy of a system. When a system is acted on by only conservative forces, the state of the system is path independent. All that matters are the starting and end points, not the points in between. Because of the path independence of systems with only conservative forces, the work done by a conservative force around a closed loop is zero.

$$W_{\text{closed path}} = \oint \vec{\mathbf{F}}_{\text{cons}} \cdot d\vec{\mathbf{r}} = 0$$

Conservative Forces, Part 2

A force is conservative if the infinitesimal work $\vec{\mathbf{F}}_{\text{cons}} \cdot d\vec{\mathbf{r}}$ is an **exact differential**.

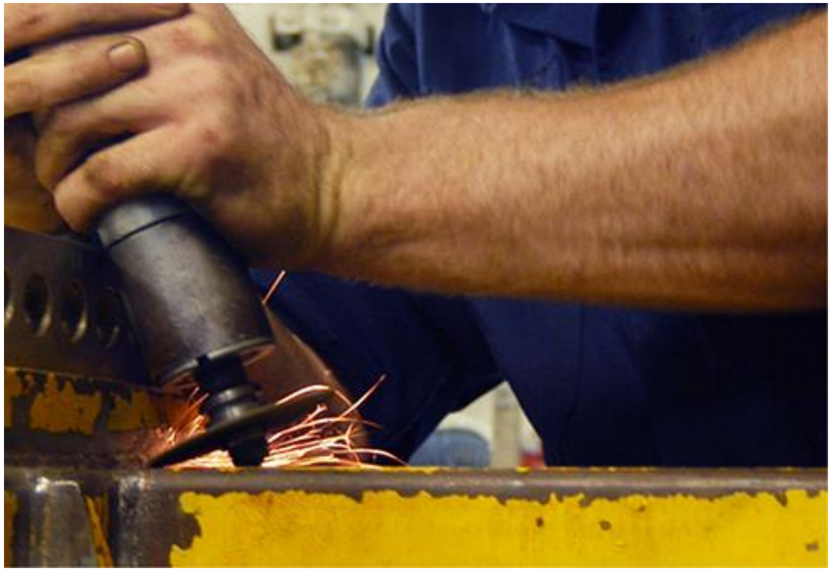
In two dimensions, this condition becomes $\frac{dF_x}{dy} = \frac{dF_y}{dx}$.

A conservative force is the negative of the spatial derivative of its associated potential energy, $F_l = -\frac{dU}{dl}$, where $\vec{\boldsymbol{l}}$ is an arbitrary vector and dl is an infinitesimal of the total magnitude, l.

Non-Conservative Forces

A **non-conservative force** is a dissipative force, like friction or air resistance, that causes a system to lose energy. When a system is acted on by such forces, the state of the system is path dependent.

A non-conservative force is never associated with a potential energy because the energy lost to the system cannot be turned into work.



(University Physics Volume 1. OpenStax. Fig. 8.7)

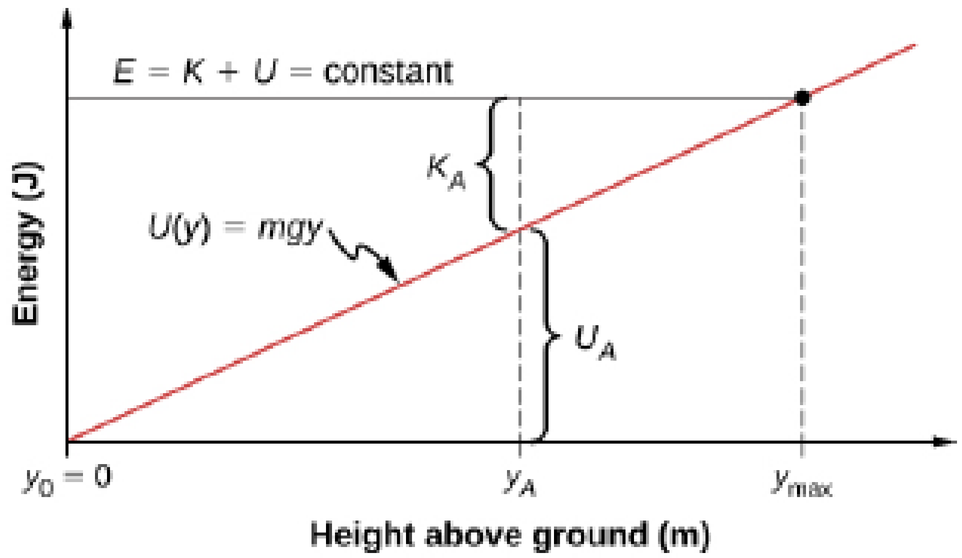
Conservation of Energy

The combined kinetic and potential energy of a system is called its **mechanical energy**, $K + U = E$. Mechanical energy is a **conserved quantity**, meaning it is neither created nor destroyed, but only transformed into other types of energy. The law of **energy conservation** states that the mechanical energy of a system remains unchanged unless a non-conservative acts on it, in which case the energy is changed by an amount identical to the work done on the system.

$$W_{\mathrm{nc},\,AB} = \Delta(K+U)_{AB} = \Delta E_{AB}$$

Potential Energy Diagrams and Stability

Potential energy diagrams are graphs of potential energy as a function of position. They can be useful tools for quickly identifying how kinetic and potential energies evolve, as well as for identifying key elements of the motion of a system.

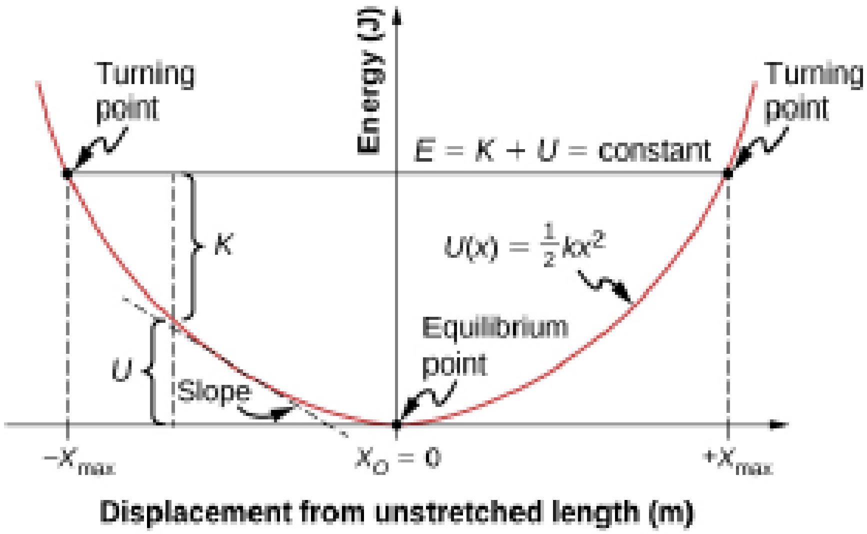


(University Physics Volume 1. OpenStax. Fig. 8.11)

Potential Energy Diagrams and Stability

A **turning point** is where potential energy is maximized and kinetic energy is minimized. They bound the system's range of motion and velocity.

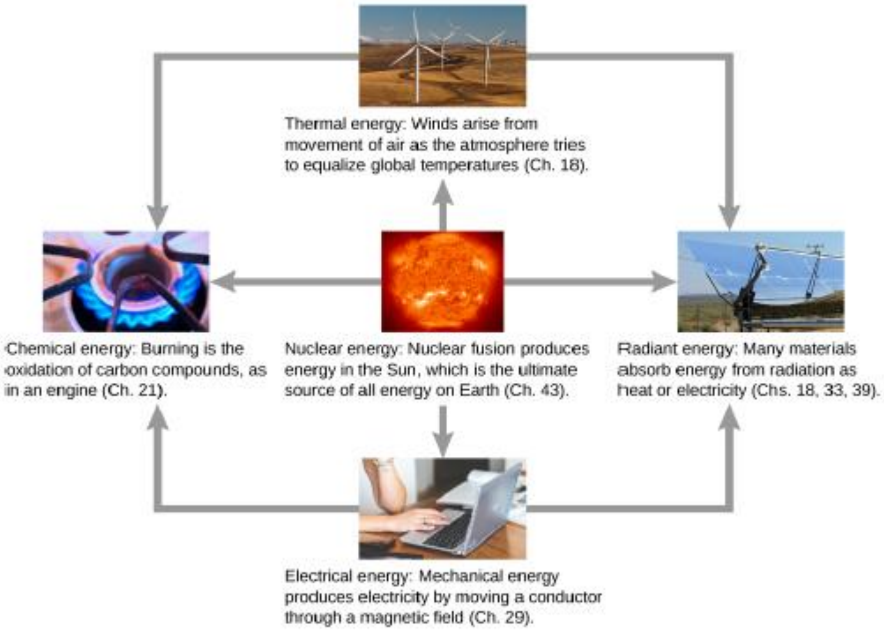
An **equilibrium point** is where potential energy is minimized. If the the graph rises on each side of the diagram, the system will return to the equilibrium point when perturbed. This is a stable equilibrium of the system.



(University Physics Volume 1. OpenStax. Fig. 8.12)

Sources of Energy

Energy is stored and can be used in many ways. Sources of energy can be broadly broken down into **renewable** and **non-renewable**. Renewable sources naturally replenish themselves rapidly enough to be consistently available. Non- renewable sources are used much faster than they are replenished. A great deal of work is currently being invested in developing renewable energy sources.



(University Physics Volume 1. OpenStax. Fig. 8.14)

How to Study this Module

- Read the syllabus or schedule of assignments regularly.
- Understand key terms; look up and define all unfamiliar words and terms.
- Take notes on your readings, assigned media, and lectures.
- As appropriate, work all questions and/or problems assigned and as many additional questions and/or problems as possible.
- Discuss topics with classmates.
- Frequently review your notes. Make flow charts and outlines from your notes to help you study for assessments.
- Complete all course assessments.

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