Energy
Energy Conservation with Isolated Systems

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Public Service Announcement: Vote!

https://registertovote.ca.gov/

Today is the deadline to register to vote in this election.

However, if you miss the deadline, you can still vote "conditionally".

Election day: Tuesday, March 3. ("Super Tuesday")

Last time

- conservative forces and potential energy
- gravitational and spring potential energies
- energy conservation

Overview

- comment about conservation laws
- work vs. potential energy (nonisolated vs. isolated system models)
- energy conservation in isolated systems

Conservation Laws

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A number of important conservation laws come up in this course (specifically, energy and linear and angular momentum).

Where do they come from? Why do they hold?

Conservation Laws

Noether's Theorem: conservation laws correspond to symmetries in the equations of motion of a system.

[1] Picture from https://www.nytimes.com/2012/03/27/science/emmy-noether-the-most-significant-mathematician-youve-never-heard-of.html

Conservation Laws

Noether's Theorem: conservation laws correspond to symmetries in the equations of motion of a system.

Energy conservation comes from a time symmetry.

[1]Picture from https://www.nytimes.com/2012/03/27/science/emmy-noether-the-most-significant-mathematician-youve-never-heard-of.html

Energy Conservation

$$W = \Delta K + \Delta U + \Delta E_{\text{int}}$$

energy transfer ↗

$\underbrace{\hspace{6em}}$ change in system's energy

Isolated and Nonisolated Systems

Isolated systems

do not exchange energy with the environment. ($W_{\text{net,ext}} = 0$)

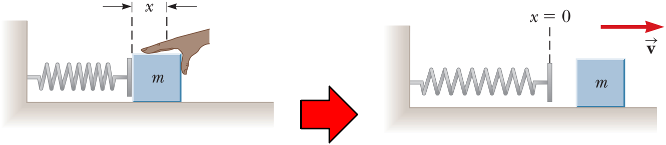
Nonisolated systems

can lose energy to the environment or gain energy from it.
(For this course: $W_{\text{net,ext}} \neq 0$)

Sometimes when solving a problem you can chose a system that is isolated, or one that is not.

Two Views: Isolated vs Nonisolated System Models

Imagine a block held up against a compressed spring and the released.



We want to find an expression for how fast it is moving after it leaves the spring by considering energy.

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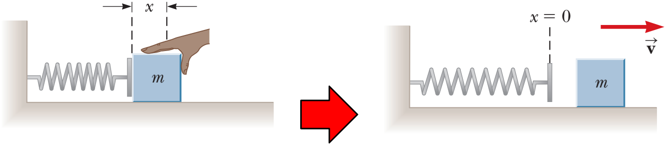

We want to find an expression for how fast it is moving after it leaves the spring by considering energy.

We have two choices for how to set up our energy conservation equation, depending on what we call our system.

Isolated System Approach

A block is released from rest on the end of a compressed spring.

System: block + spring

The spring is in our system, so the spring force $\vec{\mathbf{F}}_s$ is an internal force.

Let point i be the moment it is released; f be after it has left contact with the spring. Let $U_s = 0$ when the spring is relaxed.

$$\cancelto{0}{W_{\text{net,ext}}} = \Delta K + \Delta U$$

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$$\begin{aligned}
\cancelto{0}{W_{\text{net,ext}}} &= \Delta K + \Delta U \\
0 &= (K_f - \cancelto{0}{K_i}) + (\cancelto{0}{U_f} - U_i) \\
K_f &= U_i \\
\frac{1}{2}mv^2 &= \frac{1}{2}kx^2 \\
v &= \sqrt{\frac{k}{m}}x
\end{aligned}$$

Nonisolated System Approach

A block is released from rest on the end of a compressed spring.

System: block

Since the system does not include the spring, we can't define an elastic potential energy here. The spring force $\vec{\mathbf{F}}_s$ is an external force.

Let point i be the moment it is released; f be after it has left contact with the spring.

$$W_{\text{net,ext}} = \Delta K$$

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Let point i be the moment it is released; f be after it has left contact with the spring.

$$\begin{aligned}
W_{\text{net,ext}} &= \Delta K \\
W_s &= (K_f - \cancelto{0}{K_i}) \\
\int (F_s \,\hat{\mathbf{i}}) \cdot (\mathrm{d}x \,\hat{\mathbf{i}}) &= K_f \\
\frac{1}{2}kx^2 &= \frac{1}{2}mv^2 \\
v &= \sqrt{\frac{k}{m}}x
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Two Views: Isolated vs Nonisolated System Models

Either approach gave us the correct result.

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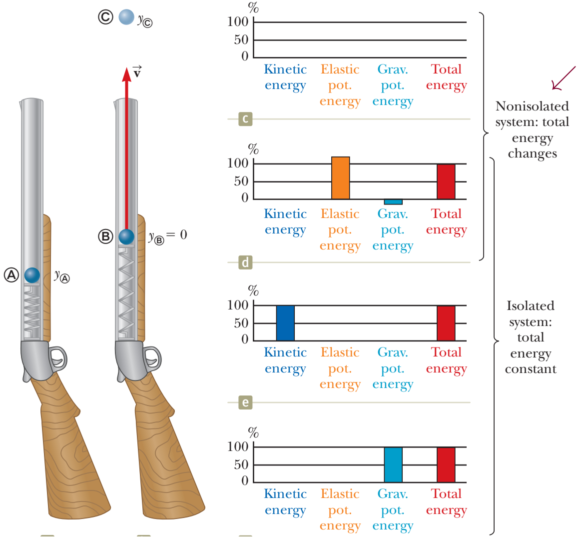
Sometimes it is not practical to include enough things in the system to make it isolated.

Isolated and Nonisolated system example

System: ball + spring + Earth



External work is done by person loading gun.

Energy Conservation

energy transferred = change in system's energy

$$W = \Delta K + \Delta U + \Delta E_{\text{int}}$$

where

- W covers **energy transfers** into or out of the system by work of an external force
- ΔK is the energy of **change in motion** of parts of the system
- ΔU is the energy of **change of configuration** of the system
- ΔE_{int} is energy converted to **heating effects from friction** in the system (or other non-conservative effects) - will do later

Energy Conservation in Isolated Systems

$$0 = \text{change in system's energy}$$

$$\cancelto{0}{W} = \Delta K + \Delta U + \Delta E_{\text{int}}$$

where

- in an **isolated system** there are **no energy transfers** into or out of the system
- ΔK is the energy of **change in motion** of parts of the system
- ΔU is the energy of **change of configuration** of the system
- ΔE_{int} is energy converted to **heating effects from friction** in the system (or other non-conservative effects) - will do later

Question: KE, Gravitational PE, and Conservation

Quick Quiz 8.3[1] A rock of mass m is dropped to the ground from a height h. A second rock, with mass 2m, is dropped from the same height. When the second rock strikes the ground, what is its kinetic energy?

(A) twice that of the first rock

(B) four times that of the first rock

(C) the same as that of the first rock

(D) half as much as that of the first rock

[2]Serway & Jewett, page 216.

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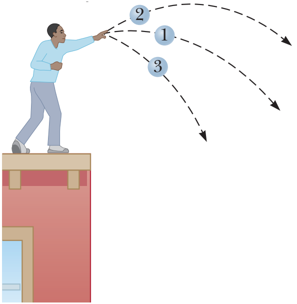
Energy of an Isolated System

Quick Quiz 8.4[2] Three identical balls are thrown from the top of a building, all with the same initial speed. As shown, the first is thrown horizontally, the second at some angle above the horizontal, and the third at some angle below the horizontal. Neglecting air resistance, rank the speeds of the balls at the instant each hits the ground, from largest to smallest.



(A) 2, 1, 3

(B) 3, 1, 2

(C) 1, 2, 3

(D) all the same

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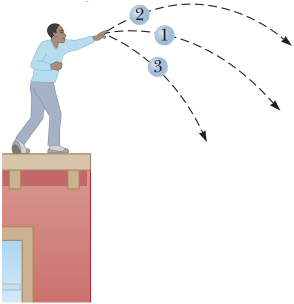

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Summary

- conservation laws
- work vs. potential energy
- energy conservation in isolated systems

Assignment 2 due tomorrow.

Next Test (Friday, Feb 28 OR Mon, Mar 2).

(Uncollected) Homework Serway & Jewett,

- Read Chapter 8.
- Ch 8, onward from page 236. Prob: 2 (isolated vs nonisolated)
- Ch 8, onward from page 236. Probs: 5, 9, 11, 45, 59, 64[3], 65

[3] Ans: $v = 1.24$ m/s