"Who first invented work, and bound the free
And holyday-rejoicing spirit down
To the ever-haunting importunity
Of business in the green fields, and the town
…?"

"Work" by Charles Lamb,
British poet and essayist (1775-1834)

"Work is of two kinds: first, altering the position of matter at or near the earth's surface relative to other such matter; second, telling other people to do so. The first kind is unpleasant and ill paid; the second is pleasant and highly paid."

"In Praise of Idleness and Other Essays" by
Bertrand Russell, British philosopher (1872-1970)

Current Assignments

For today:
- Read Sections 6.1 - 6.6

For Lecture 8:
- Read Sections 8.1, 8.2, 8.3, 8.5, 8.6

Suggested Conceptual Exercises:
- Chapter 6: 3, 5, 9, 15, 21, 27, 29, 33, 35, 37

Attend your third tutorial this week
- Quiz is on material covered last week

Homework #1 Due 11:00 AM, Thursday, Jan 31 in the Drop Box labelled for your tutorial

Writing Assignment #1
- Due 11:00 AM, Thursday, February 28

NOTE-TAKING SERVICES: ONLINE!

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Review of Lecture 6

Notes on Chaos
- Introduction to chaos
- The three-body gravitational problem
- The pendulum as an attractor
- Lorentz attractors
- Fractals

Plan for Lecture 7

Textbook, Sections 6.1 - 6.6
- Work and energy
- Gravitational and kinetic energy
- The Law of Conservation of Energy
- Transformations of energy

Chapter 6 - Conservation of Energy

6.1 Work: Using a Force to Move Something

6.2 Work and Energy: A Simple Example

6.3 A Quantitative Look at Energy

6.4 Energy: The Capacity to Do Work

6.5 The Law of Energy

6.6 Transformations of Energy

Energy

- In common English, we say something <u>has energy</u> if it can do some activity that changes the environment or itself.
- In "physics-speak", we say:
  A system has energy whenever it has the ability to do work.

What Is Work?

- In common English, we describe <u>work</u> as the effort needed to perform a task, whether physical or mental.
- In "physics-speak", we say:
  Work is done whenever an object is pushed or pulled through a distance.

  There must be both force and motion [and in the same direction].

Concept Check

Jed leans against a brick wall while Ned pushes hard against it and "works up" a sweat in the process. Who is doing work on the wall?

(a) Ned
(b) Jed
(c) Both
(d) Neither

Jed

Textbook Figure 6.1

Ned

Concept Check

Jed leans against a brick wall while Ned pushes hard against it and "works up" a sweat in the process. Who is doing work on the wall?

(a) Ned
(b) Jed
(c) Both
(d) Neither

Jed

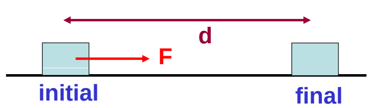
Textbook Figure 6.1

No work is done by either because the wall does not move.

Ned

The Definition of Work

Object A does work on object B if <u>A exerts a force</u> on B while B <u>moves</u> parallel to that force.

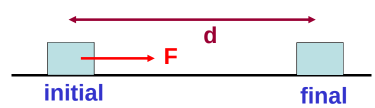


We define work done by force F as:

work = force × distance = F d

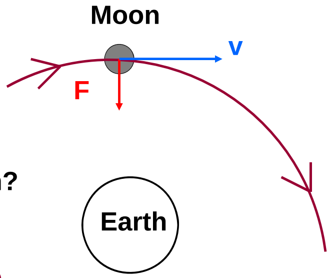
Unit: newton-meter = joule

Positive and Negative Work



If W = F d > 0 (positive work, F and d are in the same direction), then the work speeds up the object.

If W = F d < 0 (negative work, F and d are in opposite directions), then the work slows down the object.



What is the work done by F on the Moon?

Work = F d = 0

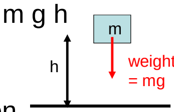
because the force is not acting in the same direction as the motion.

Speed = constant

Two Forms of Energy

Gravitational energy

- = energy an object has at its highest point
- = work done = force (weight) x height
- = weight x height = (m g) x h = m g h



Kinetic energy

- = energy associated with motion
- = ½ times the mass times the square of the speed (derived from Newton's laws)
- = ½ m v^2 or = ½ m s^2

The Energy of a Falling Object

- If you drop a book, its gravitational energy when you let it drop is the same as its kinetic energy just before it hits the floor.
- As the book falls, it loses gravitational energy and gains kinetic energy.
- The sum of the gravitational energy and the kinetic energy at any point in the book's fall stays the same.
  → Energy is conserved.

Textbook Figure 6.7

The Energy of Roller Coaster

Roller Coaster

- http://science.howstuffworks.com/engineering/structural/roller-coaster3.htm

Design your own roller coaster

- http://www.mhhe.com/physsci/physical/giambattista/roller/roller_coaster.html

Forms of Energy

- **Gravitational** energy – associated with raised objects
- **Kinetic** energy – energy of motion
- **Elastic** energy – energy of a stretched or deformed object
- **Thermal** energy – in the form of heat
- **Electromagnetic** energy – associated with electric and magnetic fields
- **Radiant** energy – energy of electromagnetic waves such as light, infrared, and X-rays
- **Nuclear** energy – involved in nuclear reactions
- **Chemical** energy – involved in chemical reactions

The Law of Conservation of Energy

Experiments have found that energy is always conserved, although it may change its form.

The total energy of all the participants in any process remains unchanged throughout that process. That is, energy cannot be created or destroyed. Energy can be transformed (changed from one form to another), and it can be transferred (moved from one place to another), but the total amount always stays the same.

Conservation of Energy: Mass on a Spring

Conservation of energy for a spring

- http://www2.biglobe.ne.jp/~norimari/science/JavaApp/energy1/e-energy1.html

An explanation of the three forms of energy

- http://id.mind.net/~zona/mstm/physics/mechanics/energy/massOnASpring/massOnASpring.html

An Alternative Version

The Work-Energy Principle:

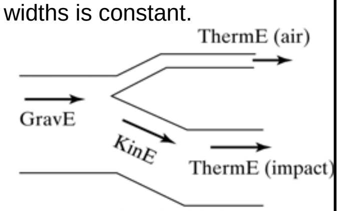
Work is an energy transfer. Work reduces the energy of the system doing the work and increases the energy of the system on which work is done, both by an amount equal to the work done.

Energy Flow Diagrams

- We can visualize energy transformations using energy flow diagrams.
  - → The width of each "pipe" indicates the amount of energy involved.
  - → The sum of the widths is constant.

Example:

The dropped book.



Energy Efficiency

Energy efficiency =
(useful output energy) / (total input energy)

Usually expressed as a percentage.

Only the part of the energy that is used to do work is considered useful.

✓ concept check 10 An operating lightbulb transforms ElectE into (a) KinE; (b) ElectE; (c) ThermE; (d) ChemE; (e) RadE.

✓ concept check 11 In the operation of a hydroelectric power plant, the energy to generate the electricity can be traced to (a) GravE in the lake behind the plant's dam; (b) ChemE in the lake behind the plant's dam; (c) ThermE in the lake behind the plant's dam; (d) RadE that comes from the sun; (e) ChemE that comes from the sun; (f) good vibes.

The high water level in the lake creates the water pressure that presses water through the turbines, (a). This water level can be further traced back to the evaporation of water that lifted it so that it could fall as rain. The sun's radiation caused this evaporation, (d).

✓ concept check 14 While a wooden matchstick burns, the energy transformation is (a) ThermE → ElectE + RadE; (b) ElectE → ThermE + RadE; (c) KinE → ChemE + RadE; (d) ChemE → KinE + RadE; (e) ThermE → ChemE + RadE; (f) ChemE → ThermE + RadE.

✓ concept check 15 Robin Hood shoots an arrow from his bow. Beginning just *before* he draws the bow, the energy transformation is (a) ChemE → ElastE → KinE; (b) ThermE → ElastE → KinE; (c) ElastE → ChemE → KinE; (d) ChemE → KinE → ElastE; (e) ElastE → KinE; (f) ThermE → ElastEly.