Physics 121.
Thursday, February 21, 2008.

Conservation of energy!
Changing kinetic energy into thermal energy.

Frank L. H. Wolfs
Department of Physics and Astronomy, University of Rochester

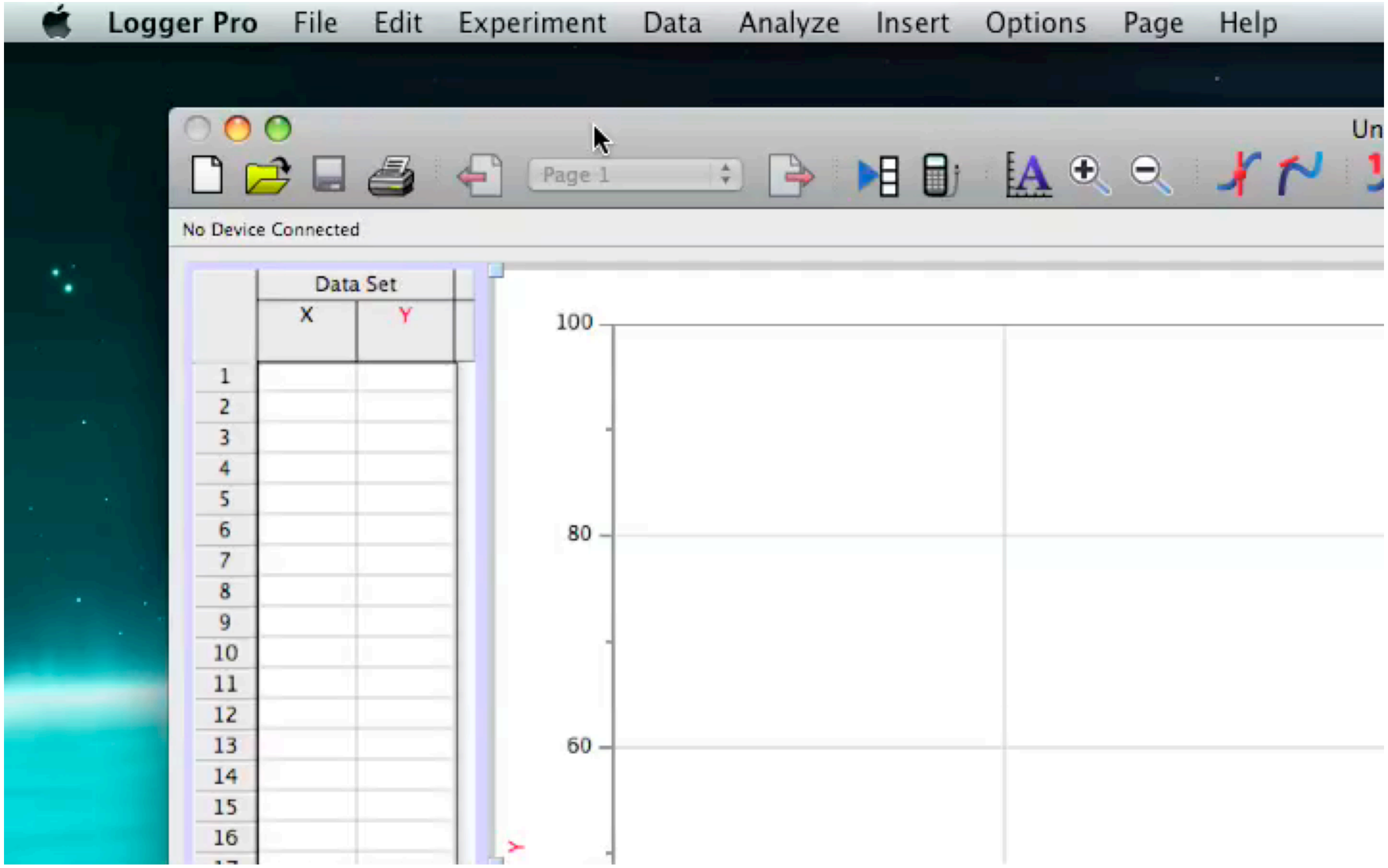
Physics 121.
Thursday, February 21, 2008.

- Topics:
  - Course information
  - Review of the concept of work and kinetic energy.
  - Conservation laws: why do we care?
  - Conservative and non-conservative forces.
  - Potential energy.

Course information.
Homework assignments.

- Homework set # 4 is due on February 23 at 8.30 am.
- There will be no homework set due on Saturday March 1.
- Homework set # 5 will be available on the WEB on Thursday morning, February 28, at 8.30 am.

Asking for help. The more details provided, the better the answer.



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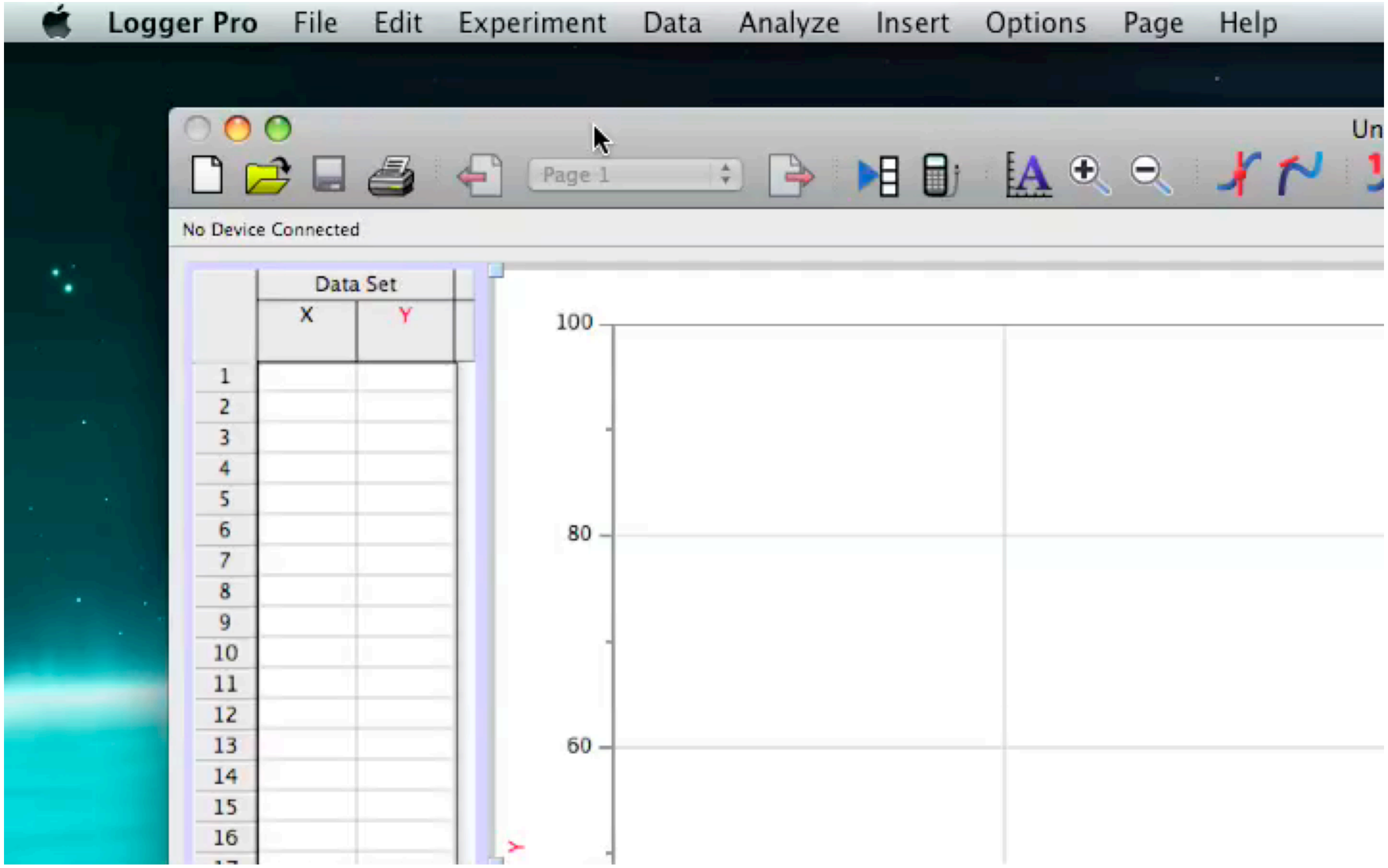


Course information.
Exam # 1.

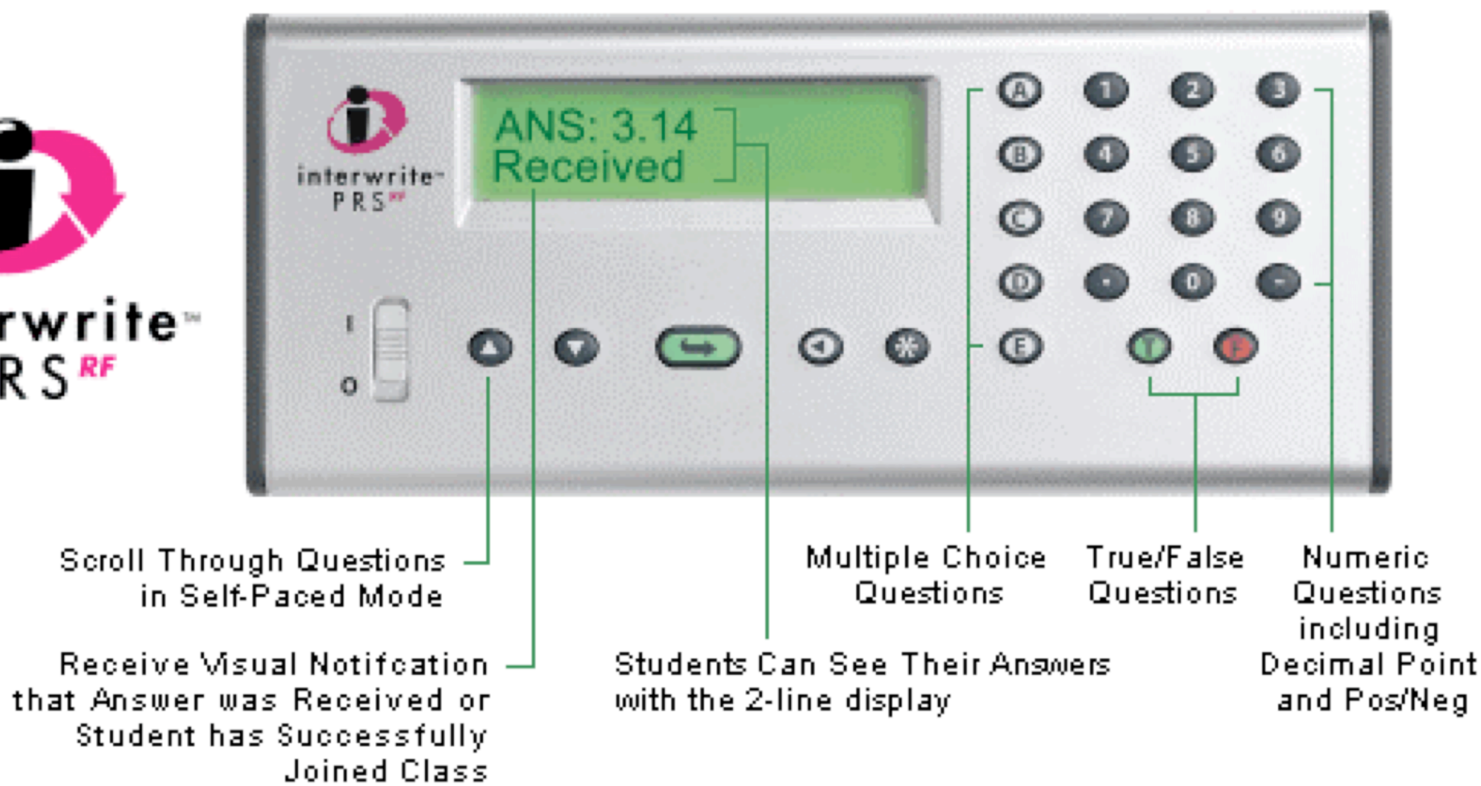
- On Thursday February 28 between 8 am and 9.30 am the first midterm exam of Physics 121 will be held. The material covered on the exam is the material covered in Chapters 1 - 6 of our text book.
- The location of the exam is Hubbell auditorium.
- There will be a normal lecture after the exam (at 9.40 am in Hoyt).
- A few remarks about the exam:
  - You will be provided with an equation sheet with all important equations used in Chapter 1 - 6.
  - If you show up late, you will just have less time to complete the exam.
  - If you miss the exam, except for valid well-documented medical reasons, you will receive a score of 0 points. Having your alarm clock die overnight is not considered a valid medical reason.
  - Any makeup exam will be a 90-minute oral exam.

Course information.
Exam # 1.

- During workshops on Monday 2/25, Tuesday 2/26, and Wednesday 2/27, the focus will be exam # 1. You can attend any (or all) workshops on these days. Bring your questions!
- There will be no workshops and office hours on Thursday 2/28 and Friday 2/29.
- There will be extra office hours on Wednesday 2/27.
- A Q&A session on the material covered on exam # 1 will take place on Tuesday evening 2/26. Time and place will be announced via email.
- You will receive the exam back during workshop during the week of March 3.
- The TAs will not see the exam until you see it.

Physics 121.
Quiz lecture 10 (postponed).

- The quiz today will have 3 questions.



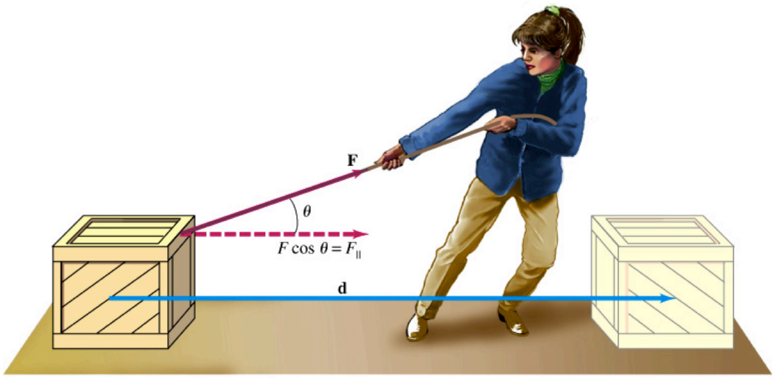
A quick review.
Work and energy.

- When a force F is applied to an object, it may produce a displacement d.

- The work W done by the force F is defined as

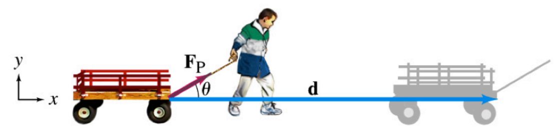
$$W = \vec{\mathbf{F}} \bullet \vec{\mathbf{d}} = Fd\cos\theta$$

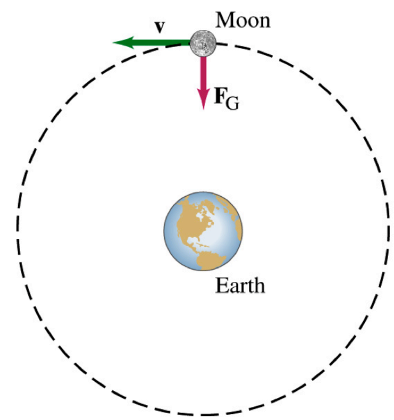
where θ is the angle between the force F and the displacement d.



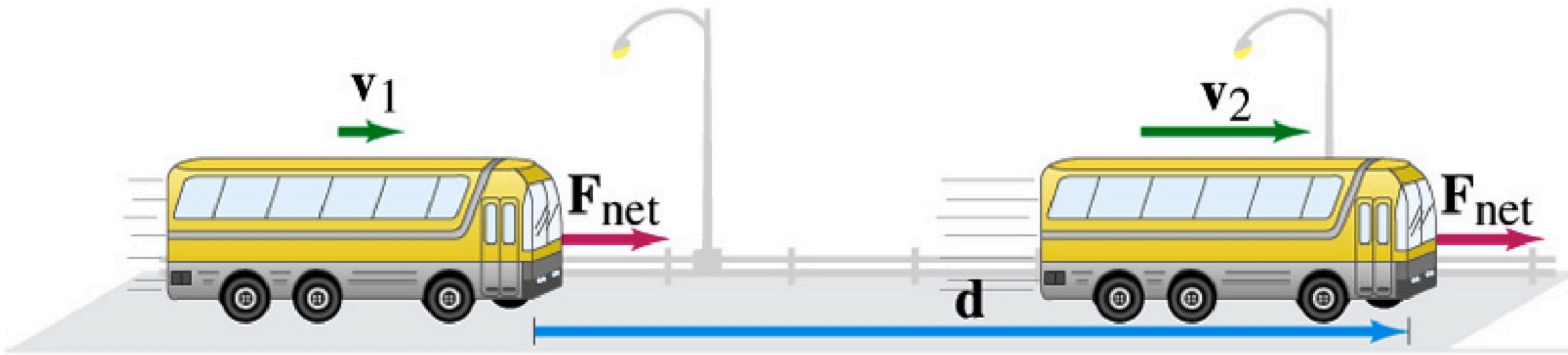
A quick review.
Work: positive, zero, or negative.

- Work done by a force can be positive, zero, or negative, depending on the angle θ:
  - If $0° \leq \theta < 90°$ (scalar product between F and $d > 0$) the speed of the object will increase.
  - $\theta = 90°$ (scalar product between F and $d = 0$) the speed of the object will not change.
  - If $90° < \theta \leq 180°$ (scalar product between F and $d < 0$) the speed of the object will decrease.



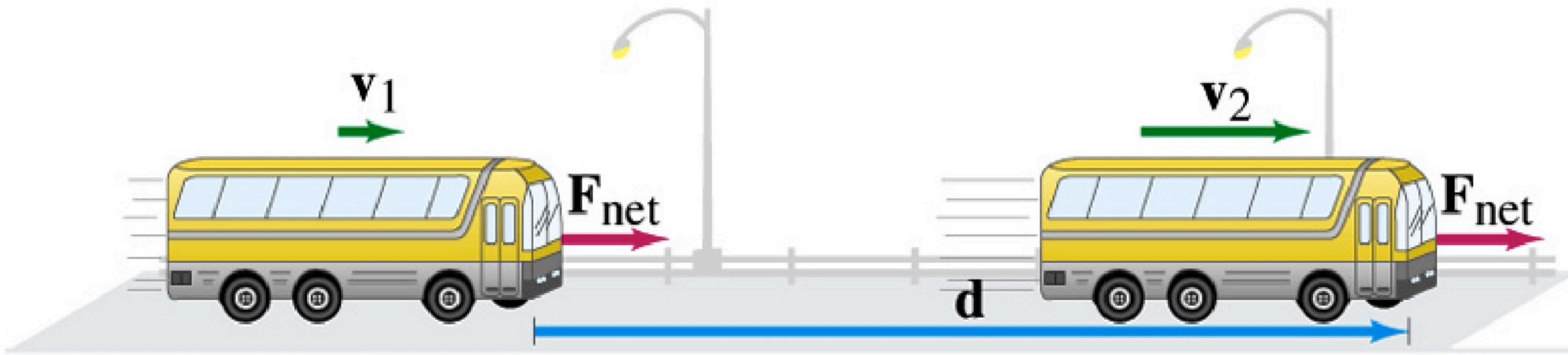


A quick review.
The work-energy theorem.



- There is a connection between the work done by a force and the change in the speed of the object:
  - If W > 0 J: speed increases
  - If W = 0 J: speed remains constant
  - If W < 0 J: speed decreases

A quick review.
The work-energy theorem.



- The work-energy theorem:

The net work done on an object is equal to the change in its kinetic energy. The kinetic energy *K* of an object with mass m, moving with velocity *v*, is equal to (1/2)mv^2.

- In the case of the bus shown above: $F_{net}\,d = 0.5mv_2^{\,2} - 0.5mv_1^{\,2}$.

Conservation of energy.

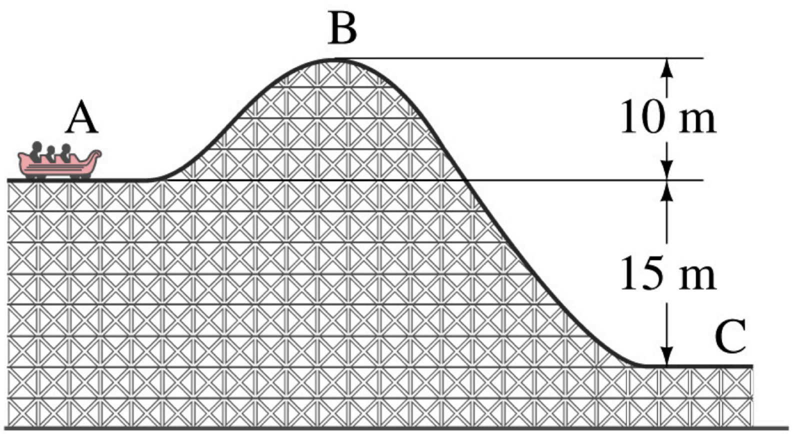
- Conservation laws in physics can be expressed in the following manner:

  "Consider a system of particles, completely isolated from outside influence. As the particles move about and interact with each other, there are certain properties of the system that do not change."

- One of the properties of closed systems that will not change is the total energy of the system. The energy may be converted from one form to another form, but the total will not change. Note: you never waste energy; you just transform it from a useful form to a useless form when you waste it!

Conservation of energy.

- Before we can apply conservation of energy, we need to define what the total energy of the system is.
- Clearly, the total energy is not equal to the kinetic energy of the components since this sum is clearly not conserved.
- In addition to kinetic energy, the system must contain potential energy (energy that has the potential to be converted into kinetic energy) in order to be conserved.



Conservation of energy.

- Consider what would happen if we define the mechanical energy of a system to be equal to the sum of the kinetic energy K and the potential energy U:

$$E = K + U$$

- If the total mechanical energy is constant, we must require that $\Delta E = 0$, or

$$\Delta K + \Delta U = 0$$

- We conclude any change in the kinetic energy ΔK must be accompanied by an equal but opposite change in the potential energy ΔU.

Potential energy in one dimension.

- Per definition, the change in potential energy is related to the work done by the force:

$$\Delta U = -W = -\int_{x_0}^{x} F(x')dx'$$

- The potential energy at x can thus be related to the potential energy at a point x_0:

$$U(x) = U(x_0) + \Delta U = U(x_0) - \int_{x_0}^{x} F(x')dx'$$

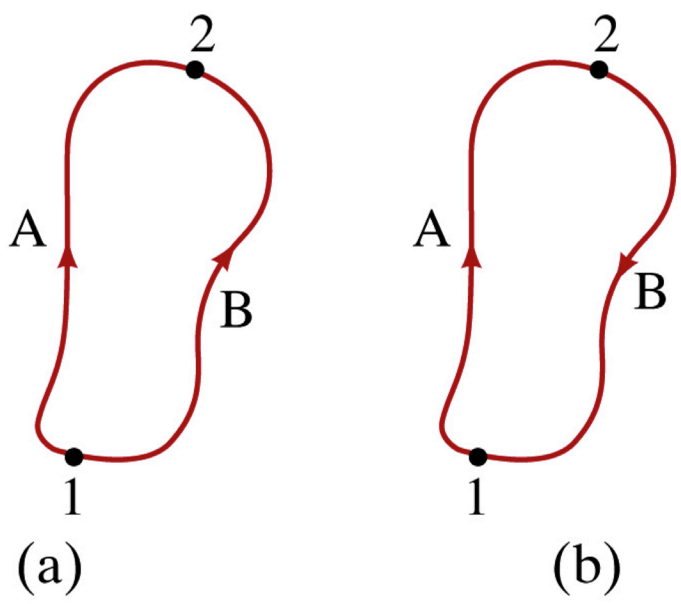
Potential energy in one dimension.

$$U(x) = U(x_0) + \Delta U = U(x_0) - \int_{x_0}^{x} F(x')\,dx'$$

- When we apply conservation of energy, we are in general only concerned with changes in the potential energy, ΔU, and not the actual value of U.
- We are free to assign a value of 0 J to the potential energy when the system is in its reference configuration.
- **Note**: the units of potential energy are the units of energy (the Joule).

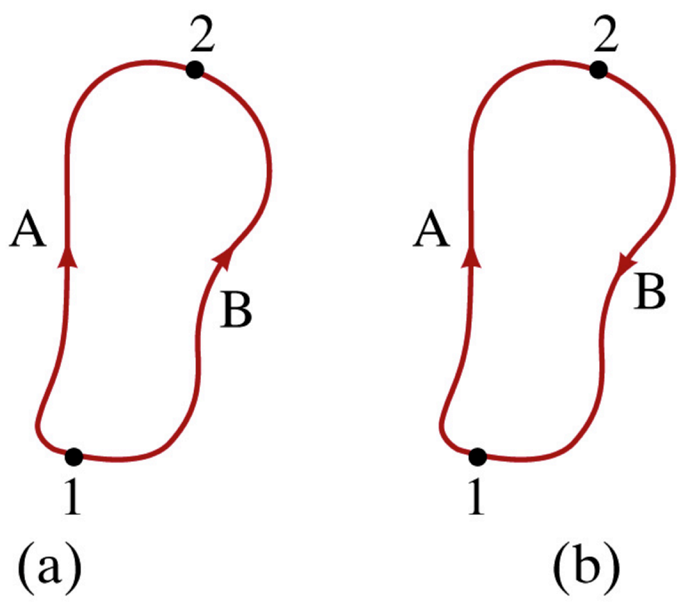
Potential energy.
Path dependence.

- The difference between the potential energy at (2) and at (1) depends on the work done by the force F along the path between (1) and (2).
- But ……. we can get from (1) to (2) via path A and via path B. In order to uniquely define the potential at (2) the work done must only depend on the start and end point, and not on the path followed.



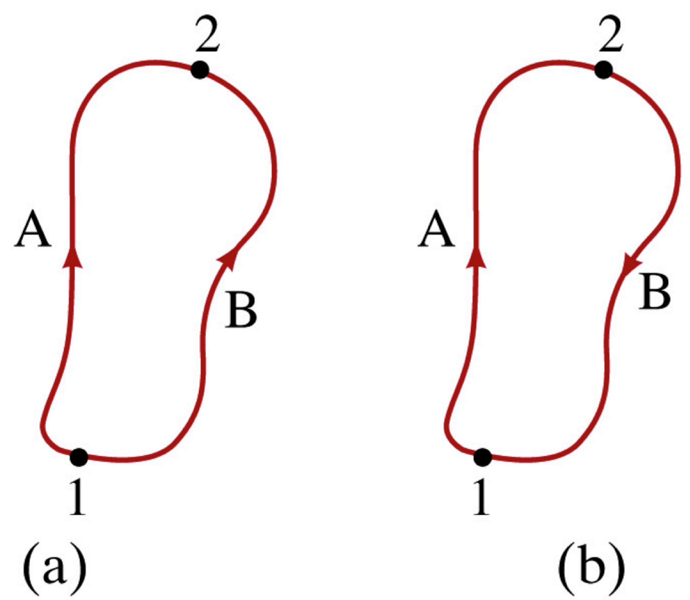
Potential energy.
Path dependence.

- The work done must only depend on the start and end point, and not on the path followed.
- This is not true for all forces. For example, the work done by the friction force is always negative. If the friction force is constant in magnitude, the work done by the friction force depends on the path length and is thus path dependent.



Potential energy.
Conservative and non-conservative forces.

- If the work is independent of the path, the work around a closed path will be equal to 0 J.
- A force for which the work is independent of the path is called a **conservative force**.
- A force for which the work depends on the path is called a **non-conservative force**.



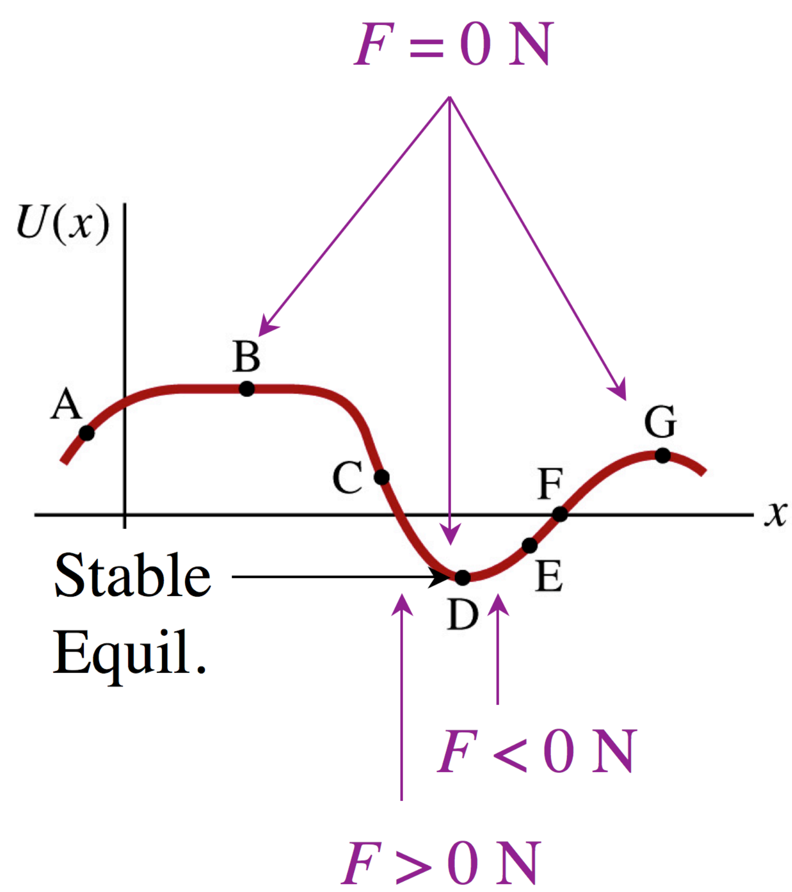
Potential energy in one dimension.

- The potential energy is directly related to the force acting on the object.
  - If we know the force, we can calculate the change dU:

$$\Delta U = -W = -\int_{x_0}^{x} F(x')dx'$$

  - If we know the change dU, we can calculate the force:

$$F(x) = -\frac{dU}{dx}$$



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Potential energy.
Examples: the spring force.

- The force exerted by a spring is given by Hooke's Law:

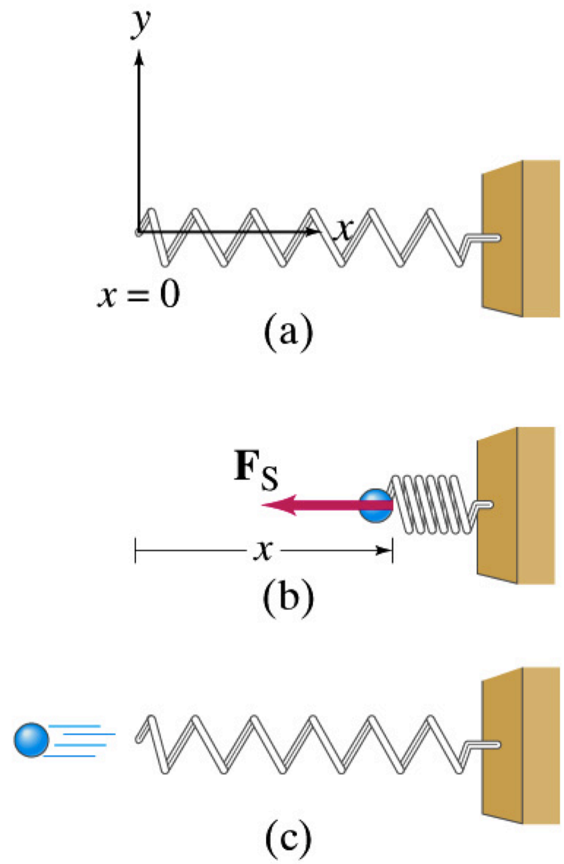
$$F(x) = -kx$$

- Consider the potential energy at x, taking the rest position as our reference point (where $U = 0$ J):

$$U(x) = U(x_0) - \int_{x_0}^{x} F(x')dx' =$$

$$= -\int_{0}^{x} (-kx')dx' = \frac{1}{2}kx^2$$

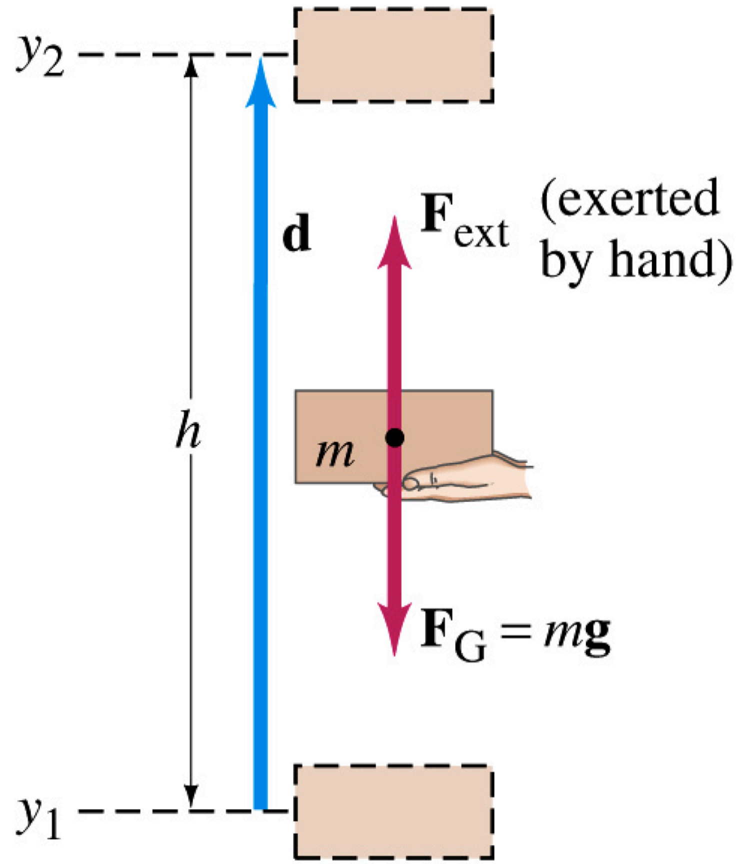
- We see that the potential energy has a minimum when $x = 0$ m.



Potential energy.
Examples: the gravitational force.

- Consider what happens when we increase the height of an object of mass *m* by *h*.
- The work done by the gravitational force is negative (force and displacement point in opposite directions) and equal in magnitude to *mgh*.
- The potential energy due to the gravitational force at position 2 is thus equal to

$$U(y_2) = U(y_1) - W = U(y_1) + mgh$$



Usually the potential energy on the surface is taken to be 0 J.

Conservation of Mechanical Energy

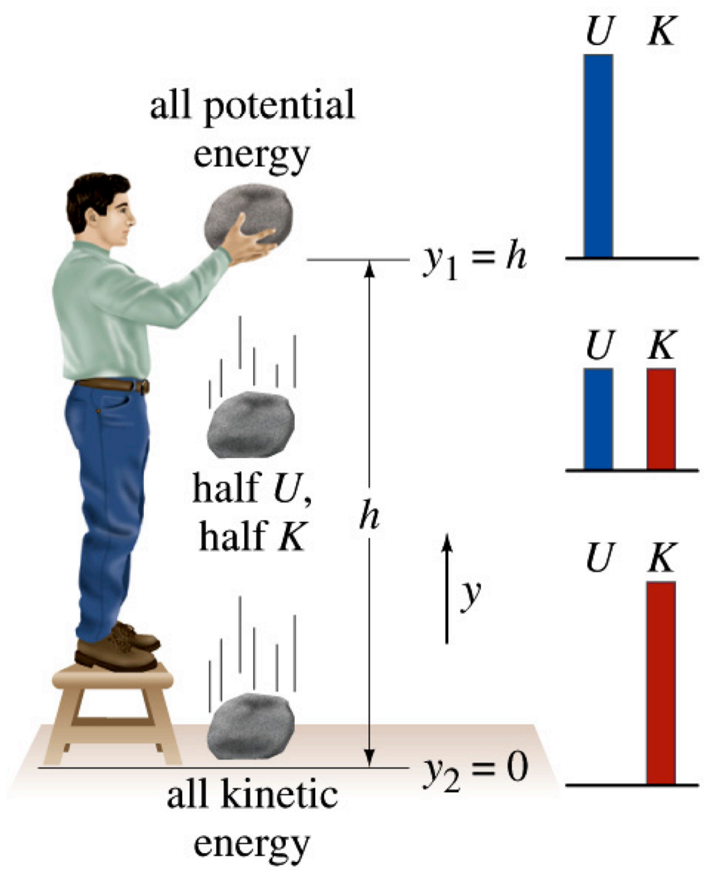
- When we drop an object, the potential energy of the object is converted to kinetic energy.
- At a height h, the total mechanical energy is mgh.
- At ground level, the total mechanical energy is $(1/2)mv^2$.
- If mechanical energy is conserved we conclude that

$$(1/2)mv^2 = mgh$$

or

$$v = (2gh)^{1/2}$$

which is independent of m.



Note: you could also use the equations of motion to find v.

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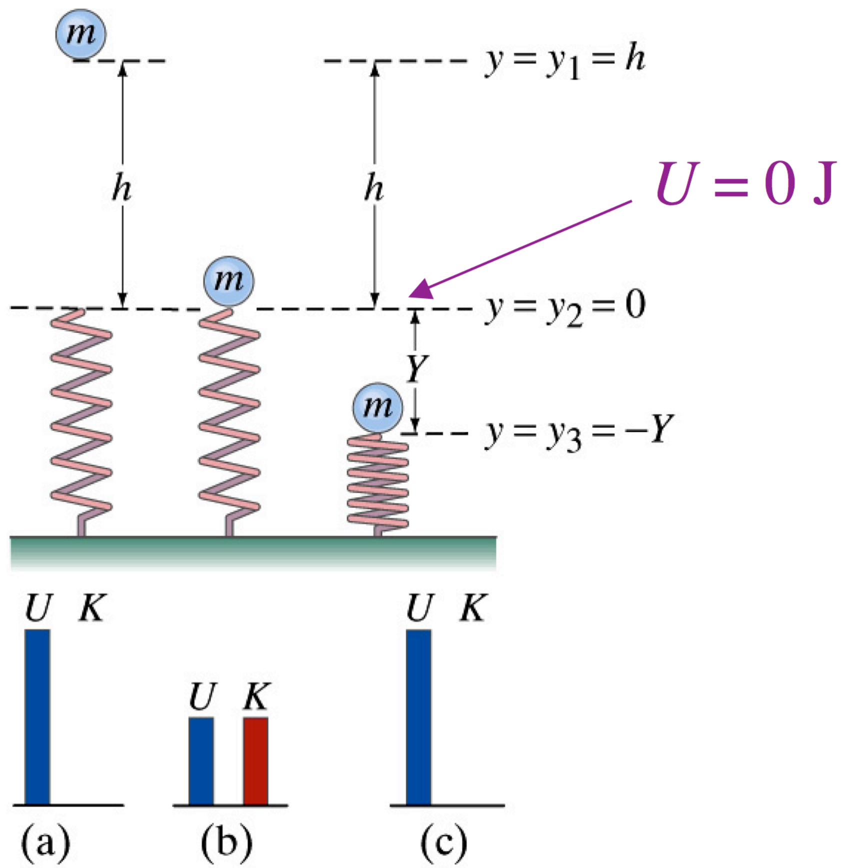
Conservation of mechanical energy.

- In this example we convert potential energy to mechanical energy and back to potential energy.
- The initial mechanical energy is all in the form of gravitational potential energy and is equal to mgh.
- The final mechanical energy is the sum of the gravitational potential energy and the potential energy associated with the compressed spring and is equal to $(1/2)kY^2 - mgY$.



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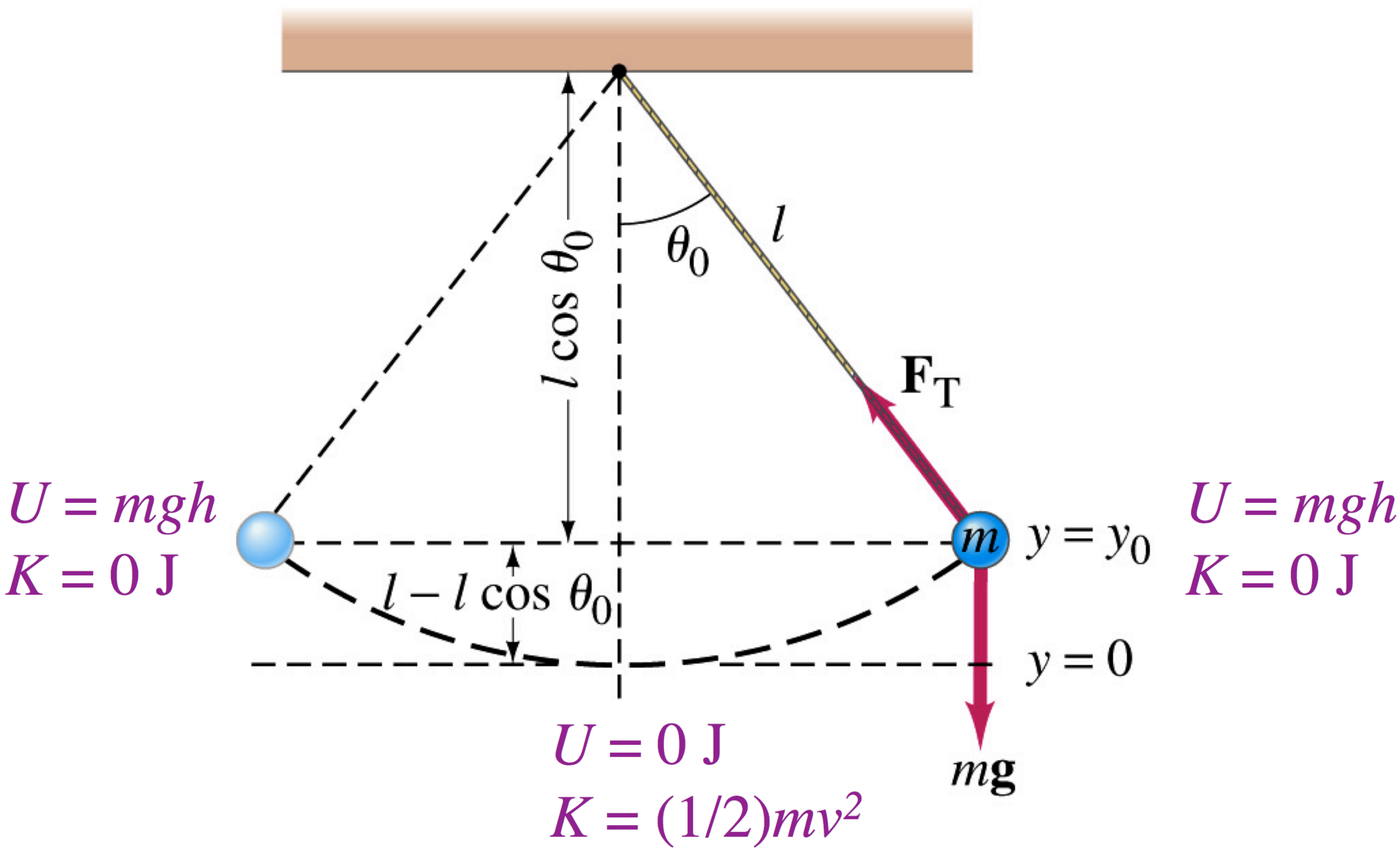
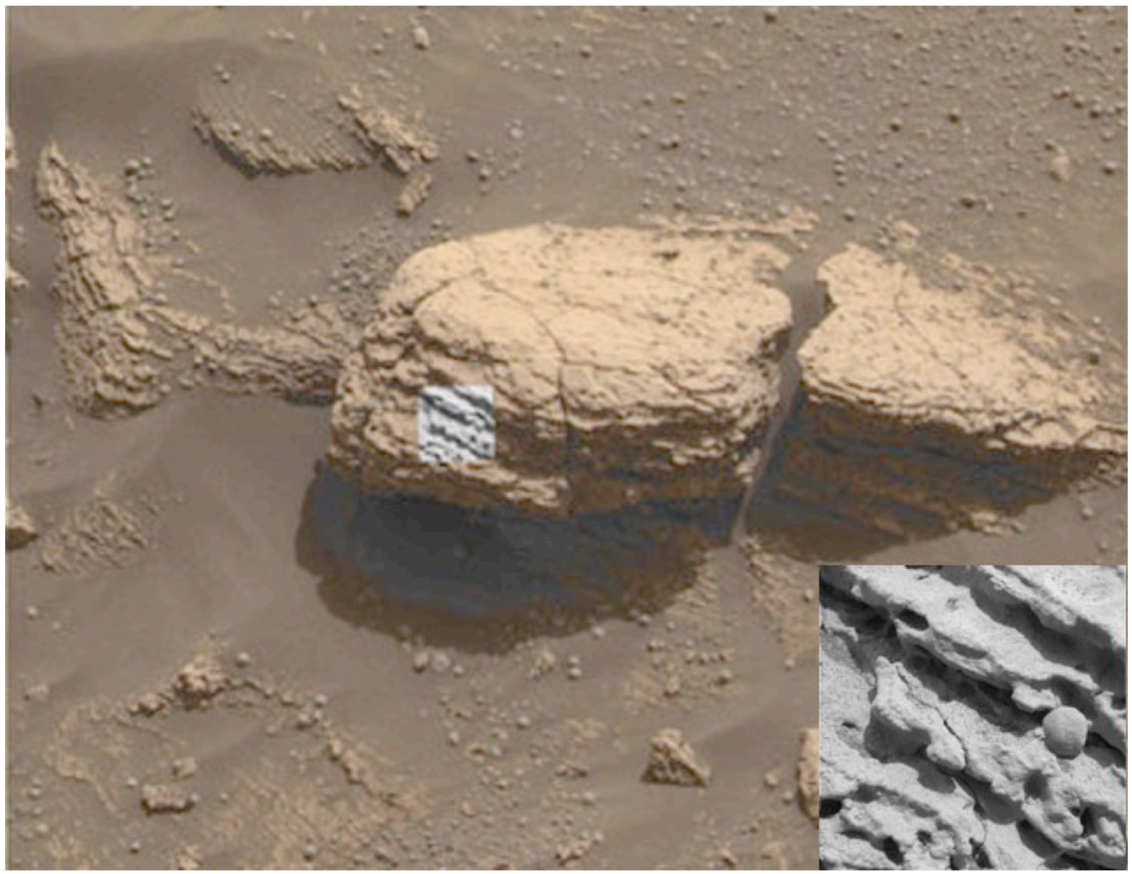
Conservation of mechanical energy.



Mechanical energy and work.

- Let's test our understanding of the concepts of mechanical energy and work by working on the following concept problems:
  - Q10.1
  - Q10.2
  - Q10.3
  - Q10.4
  - Q10.5

That's all!
Next week: more on conservation of energy.



Unusual Spherules on Mars
Credit: Mars Exploration Rover Mission, JPL, USGS, NASA