PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

Plan for Lecture 12:

Chapter 7 -- The notion of work

1. **Kinetic energy and the Work-Kinetic energy theorem**
2. **Potential energy and work; conservative forces**

5	09/07/2012	Motion in 2d	4.1-4.3	4.3,4.50	09/10/2012
6	09/10/2012	Circular motion	4.4-4.6	4.29,4.30	09/12/2012
7	09/12/2012	Newton's laws	5.1-5.6	5.1,5.13	09/14/2012
8	09/14/2012	Newton's laws applied	5.7-5.8	5.20,5.30,5.48	09/17/2012
	09/17/2012	Review	1-5		
	09/19/2012	Exam	1-5		
9	09/21/2012	More applications of Newton's laws	6.1-6.4	6.3,6.14	09/24/2012
10	09/24/2012	Work	7.1-7.4	7.1,7.15	09/26/2012
11	09/26/2012	Kinetic energy	7.5-7.9	7.31,7.41,7.49	09/28/2012
12	09/28/2012	Conservation of energy	8.1-8.5	8.6,8.22,8.35	10/01/2012
13	10/01/2012	Momentum and collisions	9.1-9.4	9.15,9.18	10/03/2012
14	10/03/2012	Momentum and collisions	9.5-9.9	9.29,9.37	10/05/2012
	10/05/2012	Review	6-9		
	10/08/2012	Exam	6-9		
15	10/10/2012	Rotational motion	10.1-10.5		10/12/2012

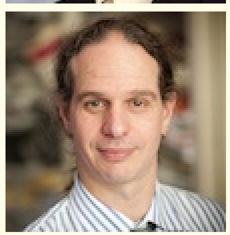
WAKE FOREST UNIVERSITY

Department of Physics

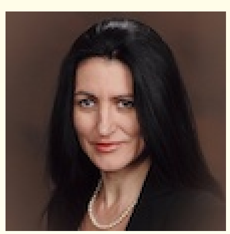
Wake Forest Physics…
Nationally recognized for teaching excellence;
internationally respected for research advances;
a focused emphasis on interdisciplinary study and close student-faculty collaboration.

News

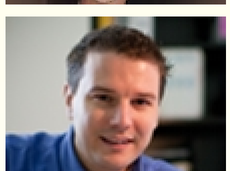
Dr. Thomas Moore to Give Public Lecture September 26



Article in WS Journal on Tech Expo Features Beet-Root Juice



Article by Lacra Negureanu of the Salsbury Group Selected for Inaugural Contribution to Proteopedia from JBSD



Prof. Thonhauser receives NSF CAREER award

Events

Wed Sep 26, 2012
Professor Thomas Moore
Rollins College
4:00 PM in Olin 101
Refreshments at 3:30 in Lobby

Wed Sep 26, 2012
Physics of the Modern Trumpet
Professor Thomas Moore
Public Lecture
7:00 PM in Olin 101

Wed Oct 3, 2012
Prof Anatoly Miroshnichenko
UNCG
4:00 PM in Olin 101
Refreshments at 3:30 in Lobby

Oct 29-30, 2012
Stuttgart NanoDays

FOREST
SITY

Department of Physics

WFU Physics Colloquium

TITLE: The Physics of the Modern Trumpet

SPEAKER: Professor Thomas Moore,

Department of Physics,
Rollins College

TIME: Wednesday September 26, 2012 at 4:00 PM

PLACE: Room 101 Olin Physical Laboratory

Refreshments will be served at 3:30 PM in the Olin Lounge. All interested persons are cordially invited to attend.

ABSTRACT

The modern trumpet has developed over the past 500 years into a highly specialized instrument that takes advantage of some very subtle physics. This presentation will include an overview of the physics of the trumpet, a discussion of the variables in trumpet design, and the results of some new research into how small vibrations of the metal affect the sound.

WFU Physics Public Lecture

TITLE: Trumpet Lessons: The physics of the modern trumpet and what it can teach us about art and science

SPEAKER: Dr. Thomas Moore,

Department of Physics,
Rollins College

TIME: Wednesday September 26, 2012 at **7:00 PM**

PLACE: Room 101 Olin Physical Laboratory

ABSTRACT

The modern trumpet is the result of a centuries-long process of trial and error. Since it was not designed using established scientific theories, an understanding of how the trumpet actually works has lagged far behind its development. This presentation will explain the science behind how trumpets are designed and what makes them sound as they do. Some myths about what makes a good trumpet will be investigated, and the relationship between the scientist and artist will be discussed.

Dr. Moore is the Archibald Granville Bush Professor of Science at Rollins College in Winter Park, FL. He earned his PhD at the Institute for Optics at the University of Rochester. He also served in the U.S. Army for twenty-one years in many capacities, among them commanding a combat arms unit, serving as a research scientist at Lawrence Livermore National Laboratory, and teaching physics at the U.S. Military Academy at West Point. His current research in musical acoustics focuses on the physics of the piano and brass instruments, and his research interests include a variety of other instruments.

PHY 113 General Physics I -- Section A

MWF 9 AM-9:50 PM	**OPL 101**	**http://www.wfu.edu/~natalie/f12phy113/**

Instructor: Natalie Holzwarth	**Phone:**758-5510	**Office:**300 OPL	**e-mail:**natalie@wfu.edu

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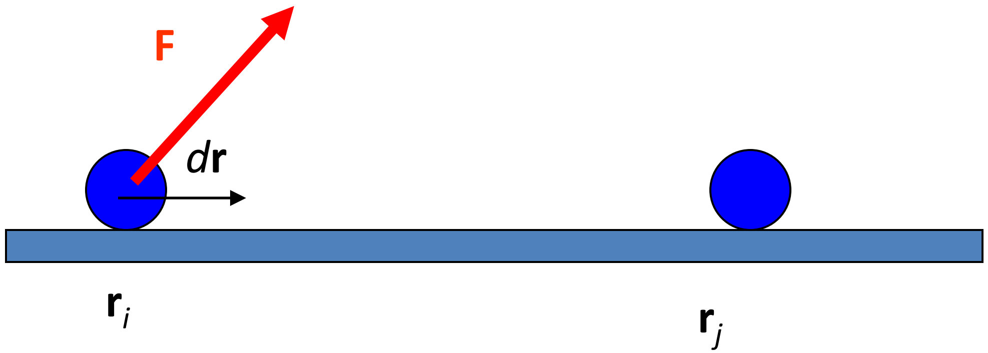
- General information
- Syllabus and homework assignments
- Lecture Notes
- For registered students

Tutorial sessions in Olin 101

- Sundays 5:00-7:00 PM -- Jiajie Xiao
- Mondays 5:00-7:00 PM -- Jiajie Xiao
- Tuesdays 5:00-7:00 PM -- Stephen Baker
- Wednesdays 5:00-7:00 PM -- Stephen Baker
- Thursdays 5:00-7:00 PM -- Loah Stevens
- Fridays 5:00-7:00 PM -- Loah Stevens

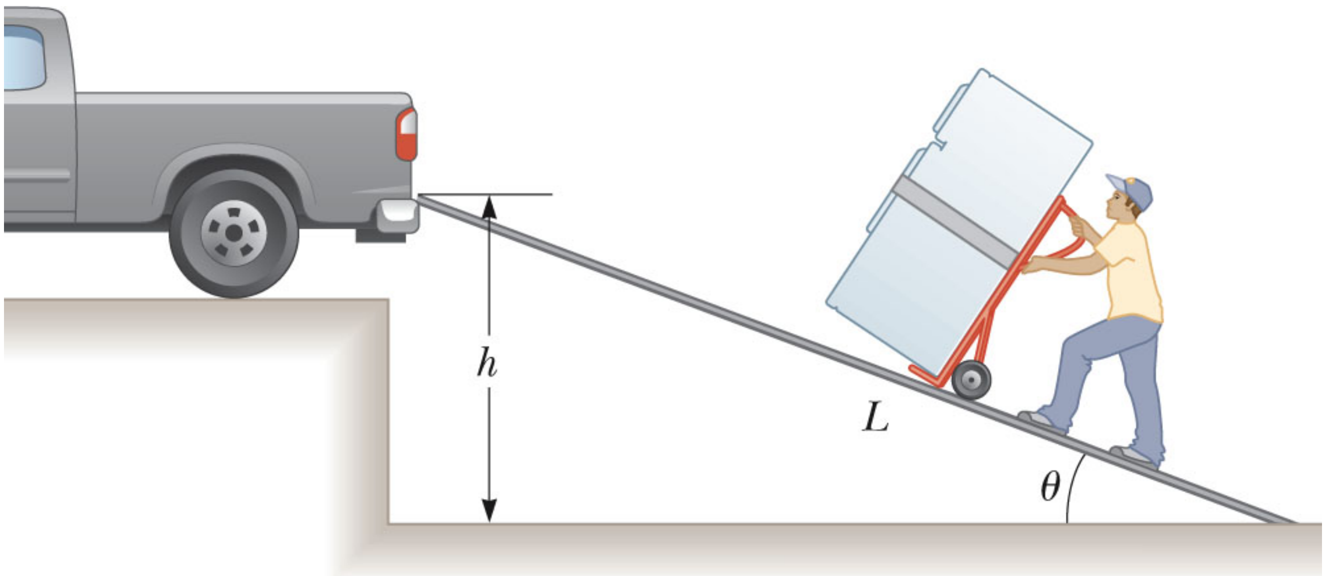
Note: Because of the special lecture, the tutorial this evening will be moved to Olin 104 after 6:30 PM.

Back to work:



$$W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r}$$

A man must lift a refrigerator of weight mg to a height h to get it to the truck.



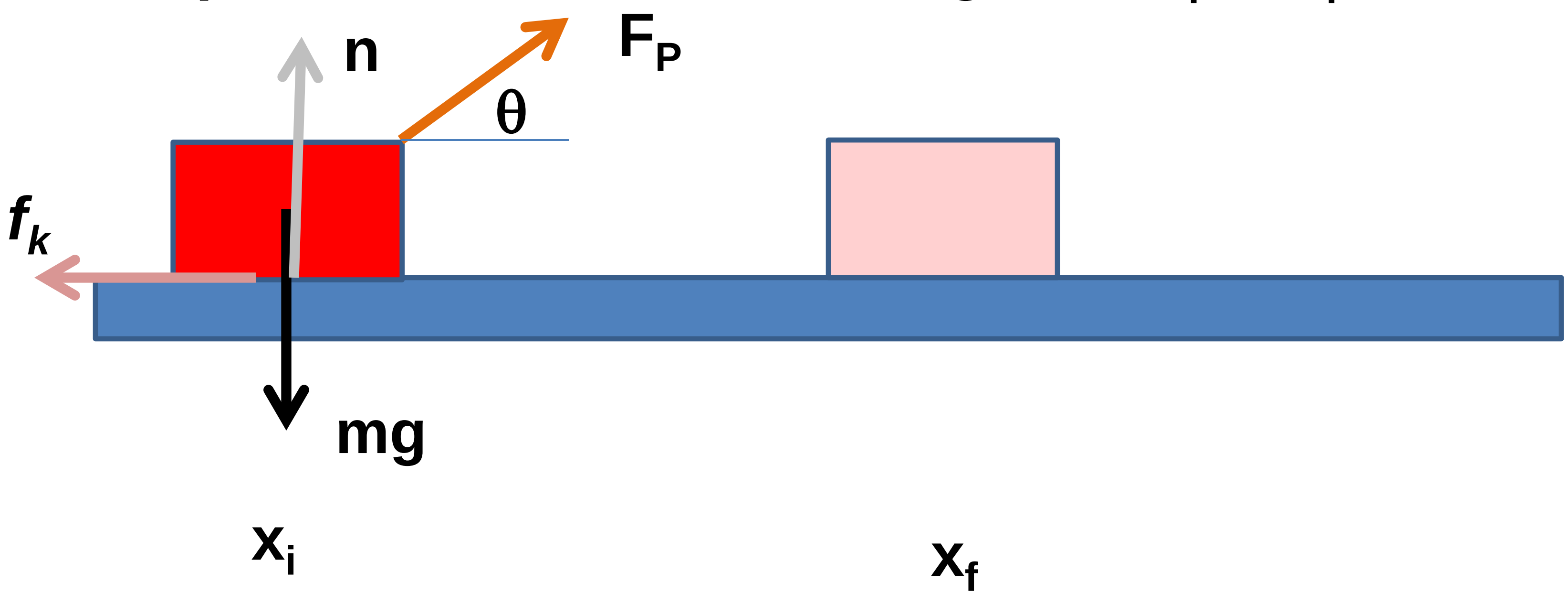
iclicker exercise:

For which method does the man do more work:

A. Vertically lifting the refrigerator at constant speed to height h?

B. Moving the refrigerator up the ramp of length L at constant speed with $h=L \sin \theta$.

Multiple forces on block moving from x_i to x_f



Assume $F_P \sin\theta \ll mg$

Work of gravity? **0**

Work of F_P? $F_P \cos\theta\,(x_f - x_i)$

Work of f_k? $-\mu_k n\,(x_f - x_i) = -\mu_k (mg - F_P \sin\theta)\,(x_f - x_i)$

iclicker exercise:

Which of the following statements about friction forces are true.

A. **Friction forces always do positive work.**
B. **Friction forces always do negative work.**
C. **Friction forces can do either positive or negative work.**

Why is work a useful concept?

Consider Newton's second law:

$\mathbf{F}_{total} = m\,\mathbf{a} \quad \Rightarrow \mathbf{F}_{total} \cdot d\mathbf{r} = m\,\mathbf{a} \cdot d\mathbf{r}$

$$\int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}_{total} \cdot d\mathbf{r} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} m\mathbf{a} \cdot d\mathbf{r} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} m \frac{d\mathbf{v}}{dt} \cdot d\mathbf{r} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} m \frac{d\mathbf{v}}{dt} \cdot \frac{d\mathbf{r}}{dt} dt = \int_{\mathbf{r}_i}^{\mathbf{r}_f} m \frac{d\mathbf{v}}{dt} \cdot \mathbf{v} dt$$

$$W_{total} = \underbrace{\tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2}_{\text{Kinetic energy (joules)}}$$

Introduction of the notion of Kinetic energy

Some more details:

Consider Newton's second law:

$\mathbf{F}_{total} = m\,\mathbf{a} \quad \Rightarrow \mathbf{F}_{total} \cdot d\mathbf{r} = m\,\mathbf{a} \cdot d\mathbf{r}$

$$\int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}_{total} \cdot d\mathbf{r} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} m\mathbf{a} \cdot d\mathbf{r} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} m \frac{d\mathbf{v}}{dt} \cdot d\mathbf{r} = \int_{t_i}^{t_f} m \frac{d\mathbf{v}}{dt} \cdot \frac{d\mathbf{r}}{dt} dt = \int_{t_i}^{t_f} m \frac{d\mathbf{v}}{dt} \cdot \mathbf{v} dt$$

$$\int_{t_i}^{t_f} m \frac{d\mathbf{v}}{dt} \cdot \mathbf{v} dt = \int_{\mathbf{v}_i}^{\mathbf{v}_f} m d\mathbf{v} \cdot \mathbf{v} = \int_i^f d\left(\frac{1}{2} m \mathbf{v} \cdot \mathbf{v}\right) = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

$$\Rightarrow W_{total} = \underbrace{\tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2}_{\text{Kinetic energy (joules)}}$$

Kinetic energy: $K = \frac{1}{2} m v^2$

units: $(kg)\,(m/s)^2 = \underbrace{(kg\ m/s^2)}_{N}\ \underbrace{m}_{m} =$ joules

Work – kinetic energy relation:

$$\boxed{W_{total} = K_f - K_i}$$

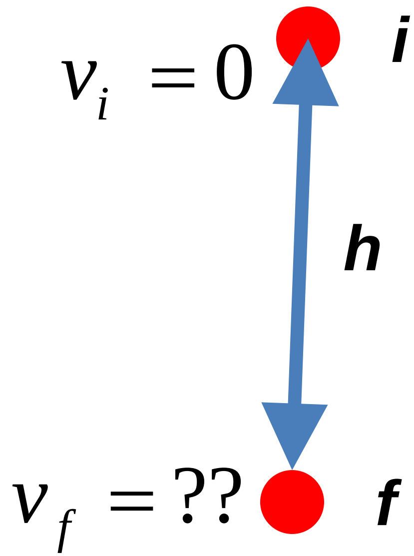
Kinetic Energy-Work theorem

$$W_{i\to f} \equiv \int_i^f \mathbf{F}_{total} \cdot d\mathbf{r} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

Example: A ball of mass 10 kg, initially at rest falls a height of 5m. What is its final velocity?

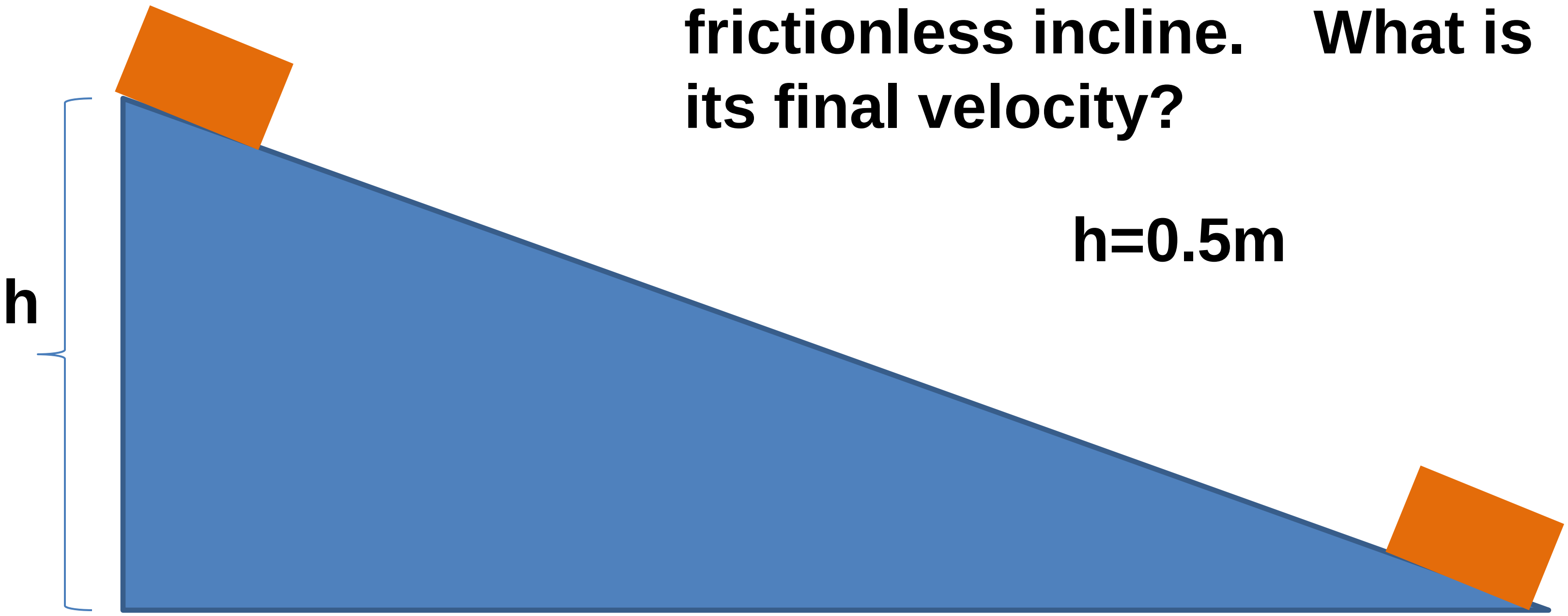
$$W_{i\to f} = mgh = \frac{1}{2}mv_f^2 - \frac{1}{2}\cancelto{0}{mv_i^2}$$

$$v_f = \sqrt{2gh} = \sqrt{(2)(9.8)(5m)} = 9.899 m/s$$



Example

A block, initially at rest at a height h, slides down a frictionless incline. What is its final velocity?



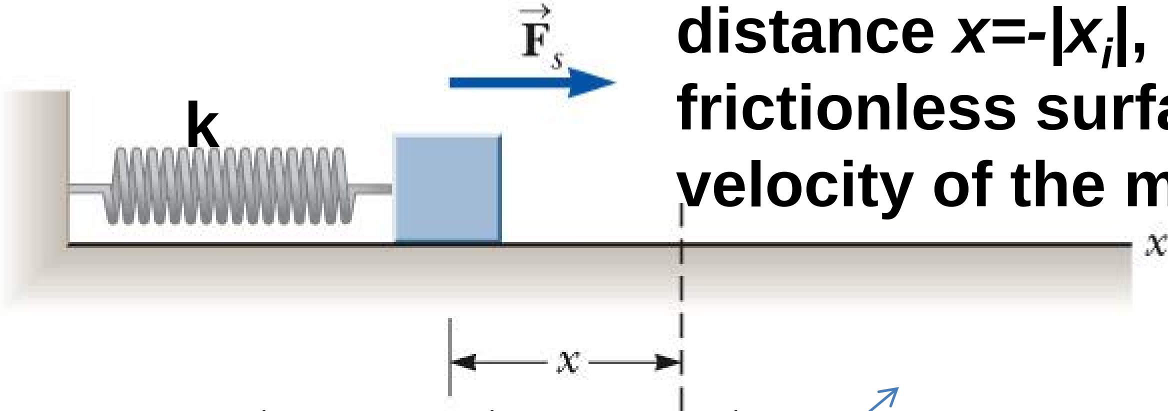
h=0.5m

$$W_{i\to f} = mgh = \frac{1}{2}mv_f^2 - \cancelto{0}{\frac{1}{2}mv_i^2}$$

$$v_f = \sqrt{2gh} = \sqrt{(2)(9.8)(0.5m)} = 3.13m/s$$

Example

A mass m initially at rest and attached to a spring compressed a distance *x*=-|*x*$_i$|, slides on a frictionless surface. What is the velocity of the mass when *x=0* ?



$$W_{i\to f} = \frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2 - \cancelto{0}{\frac{1}{2}mv_i^2}$$

$$v_f = \sqrt{\frac{k}{m}}x_i$$

For $m = 0.5kg \quad k = 5N/m \quad x_i = 0.2m$

$$v_f = \sqrt{\frac{5}{0.5}}(0.2) = 0.63m/s$$

Special case of "conservative" forces
➔conservative ⟵➔ non-dissipative

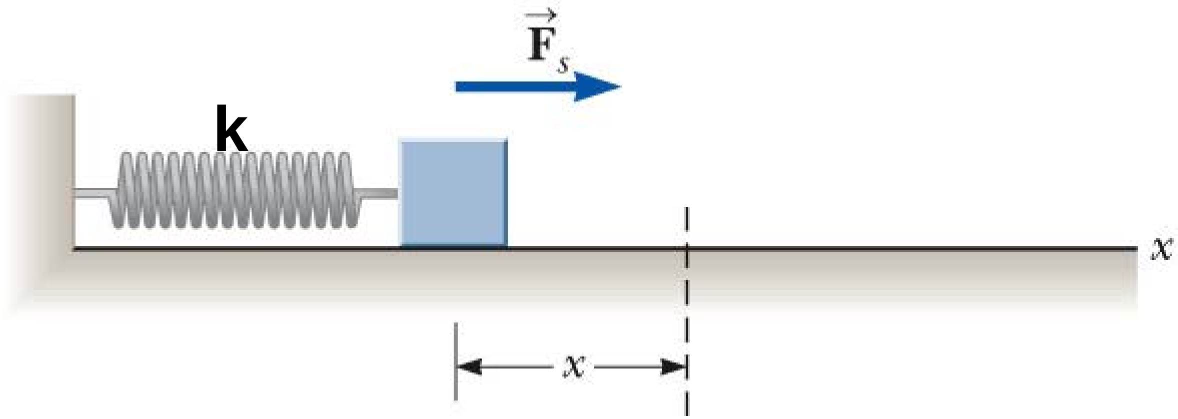
For non-dissipative forces $\mathbf{F}$, it is possible to write

$$W_{i\to f} \equiv \int_i^f \mathbf{F}\cdot d\mathbf{r} = -\left(U\left(\mathbf{r}_f\right) - U\left(\mathbf{r}_i\right)\right)$$

Example of gravity near surface of Earth:

$$W_{i\to f} \equiv \int_i^f \mathbf{F}\cdot d\mathbf{r} = -mg\left(y_f - y_i\right) = -\left(mgy_f - mgy_i\right)$$

$$\Rightarrow U(\mathbf{r}_f) = mgy_f \qquad \text{and} \qquad U(\mathbf{r}_i) = mgy_i$$



Example of spring force:

$$W_{i\to f} \equiv \int_i^f \mathbf{F}\cdot d\mathbf{r} = -\int_{x_i}^{x_f} k\,x\,dx = -\left(\tfrac{1}{2}kx_f^2 - \tfrac{1}{2}kx_i^2\right)$$

$$\Rightarrow U(\mathbf{r}_f) = \tfrac{1}{2}kx_f^2 \quad \text{and} \quad U(\mathbf{r}_i) = \tfrac{1}{2}kx_i^2$$

iclicker exercise:

Why would you want to write the work as the difference between two "potential" energies?

A. **Normal people wouldn't.**
B. **It shows a lack of imagination.**
C. **It shows that the work depends only on the initial and final displacements, not on the details of the path.**

Define potential energy function :

$$U(\mathbf{r}) \equiv -\int_{\mathbf{r}_{ref}}^{\mathbf{r}} \mathbf{F} \cdot d\mathbf{r}$$

Note that $\quad F_x = -\frac{dU}{dx}$

Work-Kinetic Energy Theorem for conservative forces:

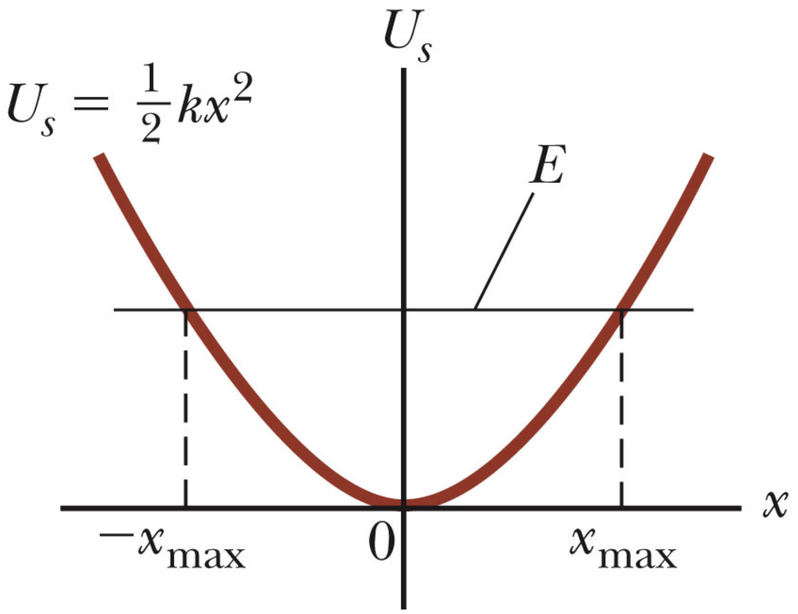
$$W_{i\to f} = -\left(U\left(\mathbf{r}_f\right) - U\left(\mathbf{r}_i\right)\right) = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$\text{Or}:$$

$$\frac{1}{2}mv_f^2 + U\left(\mathbf{r}_f\right) = \frac{1}{2}mv_i^2 + U\left(\mathbf{r}_i\right) = E \quad \text{(constant)}$$

Energy diagrams

$$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$



Note: when $x = x_{max}$:

$$v = 0, \quad E = \tfrac{1}{2}\ kx_{max}^2$$

Note: when $x = 0$:

$$U(0) = 0, \quad \tfrac{1}{2}mv^2 = \tfrac{1}{2}\ kx_{max}^2$$

Example: Model potential energy function U(x) representing the attraction of two atoms