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

Plan for Lecture 11:

Chapter 7 -- The notion of work

1. **Definition of work**
2. **Examples of work**
3. **Potential energy and work; conservative forces**
4. **Comments about Exam 1**

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		10/01/2012
13	10/01/2012	Momentum and collisions	9.1-9.4		10/03/2012

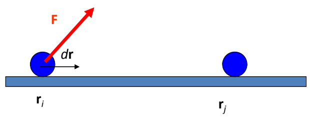
Comments about Exam 1

- **Scores 70 ≤ G ≤ 100**
- **Please keep working hard, even if your score is 90 ≤ G ≤ 100**
- **Please make an appointment to see me if your score is 70 ≤ G ≤ 90**
- **Solutions will be posted on the web on the course website (you will have to login with your WFU login and password)**

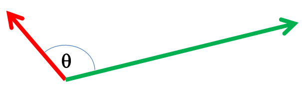
Energy ➔ work, kinetic energy

Force ➔ effects acceleration

A related quantity is **Work** $\quad W_{i \to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F} \cdot d\mathbf{r}$



Definition of vector "dot" product



$$\mathbf{A} \cdot \mathbf{B} = AB\cos\theta$$

Note that if $\theta = 90^o$, then $\mathbf{A} \cdot \mathbf{B} = 0$

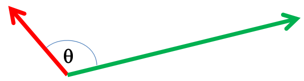
Definition of vector "dot" product

$$\mathbf{A} \cdot \mathbf{B} = AB\cos\theta$$

Example: $\quad A = 5, \quad B = 15, \quad \theta = 120^o$

$$\mathbf{A} \cdot \mathbf{B} = (5)(15)\cos 120^o = -37.5 \quad \text{(scalar)}$$

Definition of vector "dot" product -- continued



Suppose $\mathbf{A} = A_x\hat{\mathbf{i}} + A_y\hat{\mathbf{j}}$ and $\mathbf{B} = B_x\hat{\mathbf{i}} + B_y\hat{\mathbf{j}}$

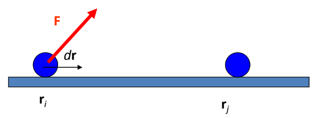
$\mathbf{A}\cdot\mathbf{B} = A_x B_x + A_y B_y$

Note that the result of a vector dot product is a scalar.

Example: $\mathbf{A} = 2\hat{\mathbf{i}} - 4\hat{\mathbf{j}}$ and $\mathbf{B} = 1\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$

$\mathbf{A}\cdot\mathbf{B} = (2)(1) + (-4)(3) = -10$

Definition of work:



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

Units of work:

Work = (Newtons)(meters) ≡ (Joules)

1 J = 0.239 cal

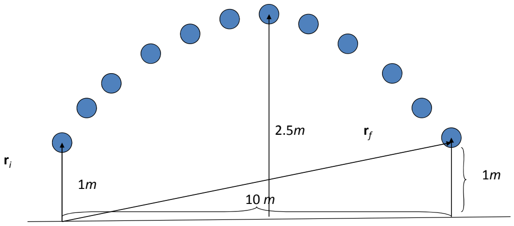
Units of work:

work = force · displacement = (N · m) = (joule)

- Only the component of force in the direction of the displacement contributes to work.
- Work is a *scalar* quantity.
- If the force is not constant, the integral form must be used.
- Work can be defined for a specific force or for a combination of forces

$$W_1 = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}_1\cdot d\mathbf{r} \quad W_2 = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}_2\cdot d\mathbf{r} \quad W_{1+2} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} (\mathbf{F}_1 + \mathbf{F}_2)\cdot d\mathbf{r} = W_1 + W_2$$

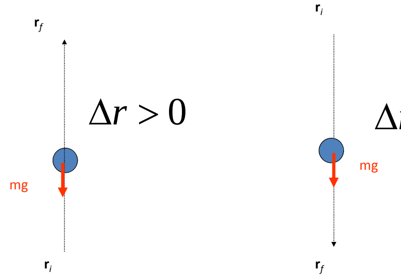
iclicker question: A ball with a weight of 5 N follows the trajectory shown. What is the work done by gravity from the initial $\mathbf{r}_i$ to final displacement $\mathbf{r}_f$?



(A) 0 J (B) 7.5 J (C) 12.5 J (D) 50 J

Gravity does negative work:

Gravity does positive work:



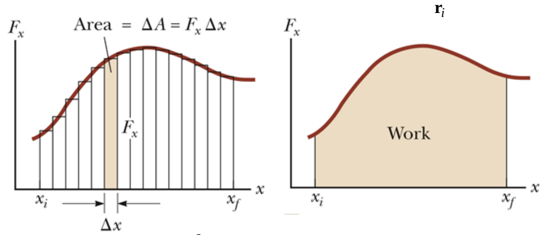
$\Delta r > 0$

$\Delta r < 0$

$W = -mg(r_f - r_i) < 0$

$W = -mg(r_f - r_i) > 0$

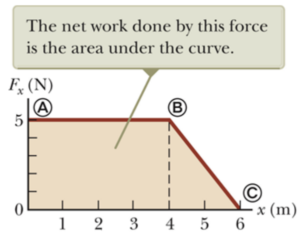
Work done by a variable force: $W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r}$



In this case:

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

Example:



$$W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r} = \int_{x_i}^{x_f} F_x dx = (5N)(4m) + \tfrac{1}{2}(5N)(2m) = 25J$$

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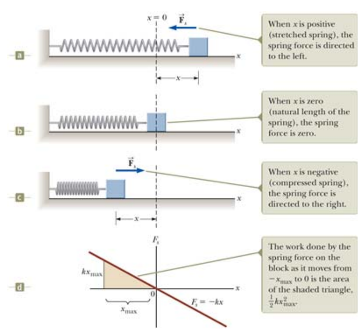
Example – spring force: F_x = - kx



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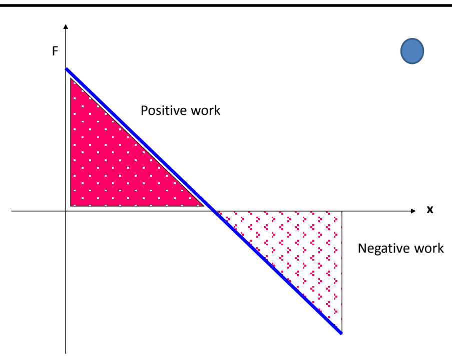

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Detail:

$$W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r} = \int_{x_i}^{x_f} F_x dx = \int_{x_i}^{x_f} (-kx)dx = -\tfrac{1}{2}kx^2\Big|_{x_i}^{x_f} = -\tfrac{1}{2}k\left(x_f^2 - x_i^2\right)$$

More examples:

Suppose a rope lifts a weight of 1000N by 0.5m at a constant upward velocity of 4.9m/s. How much work is done by the rope?

(A) 500 J (B) 750 J (C) 4900 J (D) None of these

Suppose a rope lifts a weight of 1000N by 0.5m at a constant upward acceleration of 4.9m/s^2. How much work is done by the rope?

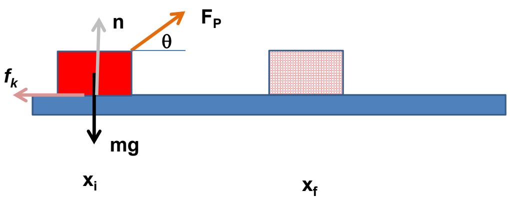
(A) 500 J (B) 750 J (C) 4900 J (D) None of these

iclicker exercise:

Why should we define work?

- **A. Because professor like to torture students.**
- **B. Because it is always good to do work**
- **C. Because it will help us understand motion.**
- **D. Because it will help us solve the energy crisis.**

Next time we will discuss the Work-Kinetic energy theorem.



Assume $F_P \sin\theta << mg$

Work of gravity? 0

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

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

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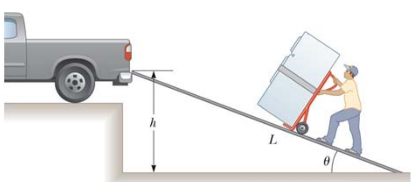
A man must lift a refrigerator of weight mg to a height h to get it to the truck.



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 $h = L \sin\theta$.

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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.

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