**PHY 113 C General Physics I**
**11 AM-12:15 PM MWF Olin 101**

**Plan for Lecture 9:**

1. **Review (Chapters 1-8)**
2. **Exam preparation advice –**
3. **Example problems**



| No. | Lecture Date | Topic | Text Sections | Problem Assignments | Assignment Due Date |
|---|---|---|---|---|---|
| 1 | 08/27/2013 | Quantitative Measurement | 1.1-1.6 | Practice problems | 09/03/2013 |
| 2 | 08/29/2013 | Motion in one dimension | 2.1-2.8 | 2.9, 2.19, 2.51, 2.58 | 09/03/2013 |
| 3 | 09/03/2013 | Vectors | 3.1-3.4 | 3.20, 3.24, 3.48 | 09/05/2013 |
| 4 | 09/05/2013 | Motion in two dimensions | 4.1-4.6 | 4.1, 4.12, 4.36, 4.60 | 09/10/2013 |
| 5 | 09/10/2013 | Newton's Laws | 5.1-5.8 | 5.15, 5.29, 5.42, 5.47 | 09/12/2013 |
| 6 | 09/12/2013 | Newton's Laws -- more examples | 6.1-6.4 | 5.52, 5.66, 6.3, 6.4 | 09/17/2013 |
| 7 | 09/17/2013 | Energy | 7.1-7.9 | 7.3, 7.15, 7.31, 7.34 | 09/19/2013 |
| 8 | 09/19/2013 | Energy continued | 8.1-8.5 | 7.55, 8.5, 8.23 | 09/24/2013 |
| 9 | 09/24/2013 | Review Chapters 1-8 | 1-8 | | |
| | 09/26/2013 | Exam on Chapters 1-8 | | | |
| 10 | 10/01/2013 | Linear Momentum | 9.1-9.9 | | 10/03/2013 |
| 11 | 10/03/2013 | Rotational Motion | 10.1-10.9 | | 10/08/2013 |
| 12 | 10/08/2013 | Angular Momentum | 11.1-11.6 | | 10/10/2013 |
| 13 | 10/10/2013 | Universal Gravitation | 13.1-13.6 | | 10/15/2013 |



***iclicker question***

**What is the best way to prepare for Thursday's exam?**

A. **Read Lecture Notes and also reread Chapters 1-8 in Serway and Jewett.**
B. **Prepare equation sheet.**
C. **Solve problems from previous exams.**
D. **Solve homework assignments (both graded and ungraded) from Webassign Assignments 1-8**
E. **All the above**

**iclicker question**
**Have you (yet) accessed the online class lecture notes from previous classes?**

A. yes
B. no

**iclicker question**
**Have you (yet) accessed the passed Webassign Assignments (with or without the answer key)?**

A. yes
B. no



## Access to previous exams

### PHY 113 General Physics I -- Section C

| | | |
|---|---|---|
| TR 11 AM-12:15 PM | OPL 101 | http://www.wfu.edu/~natalie/f13phy113/ |

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

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

**Tutorials starting September 2, 2013 (Olin 101)**

- Mondays 5:00-7:00 PM -- John Byrum
- Tuesdays 5:00-7:00 PM -- Billy Nicholson; 7:00-9:00 PM -- John Byrum
- Wednesdays 5:30-7:30 PM -- Junwei Xu
- Thursdays 5:00-7:00 PM -- Travis Jones; 7:00-9:00 PM -- Junwei Xu.



## Previous exam access -- continued

### PHY 113 General Physics I -- Section C

| | | |
|---|---|---|
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| | | | |
|---|---|---|---|
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**Exams from previous years**

1. Exam 1: Questions Solutions
2. Exam 2: Questions Solutions
3. Exam 3: Questions Solutions
4. Exam 4: Questions Solutions

**Overlap with 2013 schedule**

**Comments on preparation for next Thursday's exam – continued**

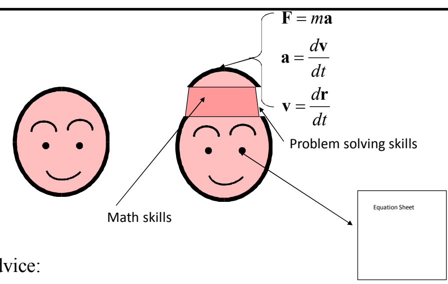
**What you should bring to the exam (in addition to your well-rested brain):**

- **A pencil or pen**
- **Your calculator**
- **An 8.5"x11" sheet of paper with your favorite equations (to be turned in together with the exam)**

**What you should NOT use during the exam**

- **Electronic devices (cell phone, laptop, etc.)**
- **Your textbook**






Advice:

1. Keep basic concepts and equations at the top of your head.
2. Practice problem solving and math skills
3. Develop an equation sheet that you can consult.



***iclicker exercise***

**Does the previous slide annoy you?**

A. **yes**
B. **no**

Problem solving steps

1. Visualize problem – labeling variables
2. Determine which basic physical principle(s) apply
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (same number of knowns and unknowns).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).



**Likely exam format (example from previous exam)**

September 15, 2012

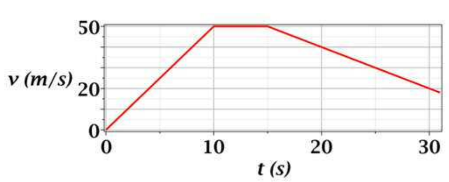
PHY 113 A – First Exam

Note: This exam has 4 problems each worth 25 points. Please record all of your work (diagrams, mathematical manipulations, and numerical work) in the exam booklet. Please show your intermediate steps so that partial credit can be awarded if appropriate. When your work is completed, please turn in: (1) the exam booklet, (2) your equation sheet, and (3) this exam paper. It is assumed that all work will be done under the guidelines of the honor code.

**Useful constants**
Gravitational acceleration near Earth's surface $g$: 9.8 m/s$^2$



**Likely exam format (example from previous exam)**




1.

The figure above shows a plot of the one-dimensional velocity $v(t)$ versus time $t$ of an object. Use this graph the determine the following:

(a) What is the instantaneous acceleration at $t = 5$ s: $a(5s)$?
(b) What is the instantaneous acceleration at $t = 12$ s: $a(12s)$?
(c) What is the instantaneous acceleration at $t = 20$ s: $a(20s)$?
(d) What distance does the particle travel during the time $0 \leq t \leq 15s$: $[x(15s) - x(0s)]$?

## Review of slides from previous lectures

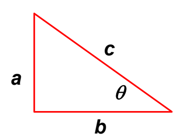


## Mathematics Review -- Appendix B Serwey & Jewett

Quadratic equation:

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$




Trigonometry:

$$\cos\theta = \frac{b}{c}$$

$$\sin\theta = \frac{a}{c}$$

$$\tan\theta = \frac{a}{b}$$

Differential calculus:

$$\frac{d}{dt} at^n = ant^{n-1}$$

$$\frac{d}{dt} e^{\alpha t} = \alpha e^{\alpha t}$$

$$\frac{d}{dt}\sin(\beta t) = \beta\cos(\beta t)$$

Integral calculus:

$$\int at^n dt = \frac{at^{n+1}}{n+1}$$

$$\int e^{\alpha t} dt = \frac{1}{\alpha} e^{\alpha t}$$

$$\int \sin(\beta t) dt = -\frac{1}{\beta}\cos(\beta t)$$



## One dimensional motion -- Summary of relationships

$$v(t) = \frac{dx}{dt} \Leftrightarrow x(t) = \int_{t_0}^{t} v(t')dt'$$

$$a(t) = \frac{dv}{dt} \Leftrightarrow v(t) = \int_{t_0}^{t} a(t')dt'$$

**Special relationships between *t,x,v,a* for constant *a*:**

General relationship :

$$v(t) = \frac{dx}{dt} \quad \Leftrightarrow \quad x(t) = \int_{t_0}^{t} v(t')dt'$$

$$a(t) = \frac{dv}{dt} \quad \Leftrightarrow \quad v(t) = \int_{t_0}^{t} a(t')dt'$$

Special relationship :

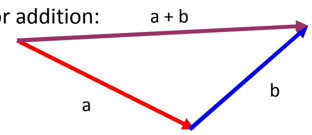
$$v(t) = v(0) + at \equiv v_0 + at$$

$$x(t) = x(0) + v(0)t + \frac{1}{2}at^2 \equiv x_0 + v_0 t + \frac{1}{2}at^2$$

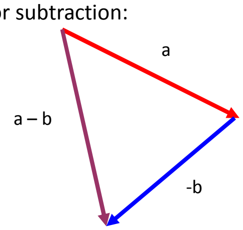


**Introduction of vectors**

Vector addition:

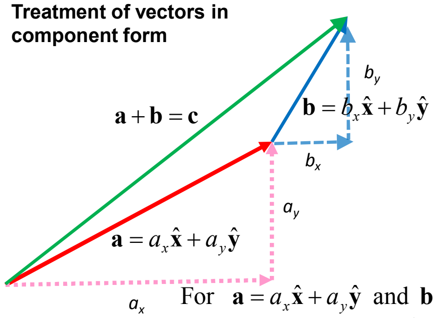



Vector subtraction:






**Treatment of vectors in component form**




For $\mathbf{a} = a_x\hat{\mathbf{x}} + a_y\hat{\mathbf{y}}$ and $\mathbf{b} = b_x\hat{\mathbf{x}} + b_y\hat{\mathbf{y}}$

$$\mathbf{a} + \mathbf{b} = (a_x + b_x)\hat{\mathbf{x}} + (a_y + b_y)\hat{\mathbf{y}} = \mathbf{c}$$

$$|\mathbf{c}| = \sqrt{c_x^2 + c_y^2}$$

## Vectors relevant to motion in two dimenstions

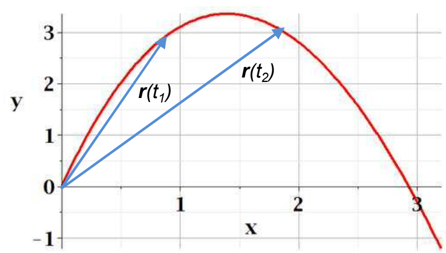
**Displacement:** $\mathbf{r}(t) = x(t)\,\mathbf{i} + y(t)\,\mathbf{j}$

**Velocity:** $\mathbf{v}(t) = v_x(t)\,\mathbf{i} + v_y(t)\,\mathbf{j}$ $\quad \mathbf{v}_x = \frac{dx}{dt} \quad \mathbf{v}_y = \frac{dy}{dt}$

**Acceleration:** $\mathbf{a}(t) = a_x(t)\,\mathbf{i} + a_y(t)\,\mathbf{j}$ $\quad \mathbf{a}_x = \frac{dv_x}{dt} \quad \mathbf{a}_y = \frac{dv_y}{dt}$



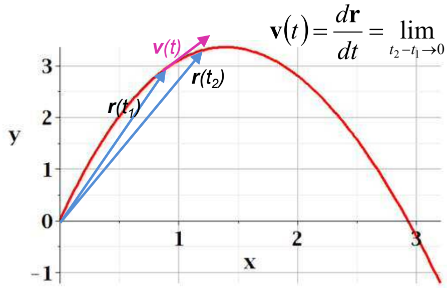
## Visualization of the position vector *r(t)* of a particle





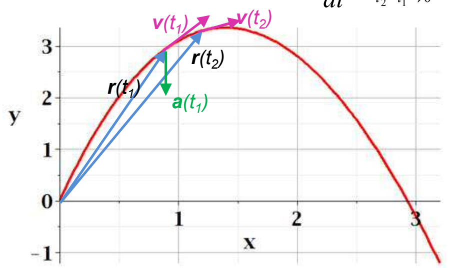

## Visualization of the velocity vector *v(t)* of a particle

$$\mathbf{v}(t) = \frac{d\mathbf{r}}{dt} = \lim_{t_2 - t_1 \to 0} \frac{\mathbf{r}(t_2) - \mathbf{r}(t_1)}{t_2 - t_1}$$



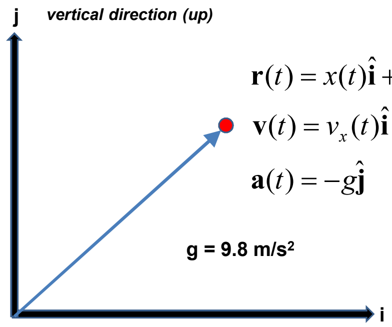
**Visualization of the acceleration vector *a(t)* of a particle**

$$\mathbf{a}(t) = \frac{d\mathbf{v}}{dt} = \lim_{t_2 - t_1 \to 0} \frac{\mathbf{v}(t_2) - \mathbf{v}(t_1)}{t_2 - t_1}$$






**Projectile motion (near earth's surface)**




$$\mathbf{r}(t) = x(t)\hat{\mathbf{i}} + y(t)\hat{\mathbf{j}}$$

$$\mathbf{v}(t) = v_x(t)\hat{\mathbf{i}} + v_y(t)\hat{\mathbf{j}}$$

$$\mathbf{a}(t) = -g\hat{\mathbf{j}}$$

g = 9.8 m/s$^2$



**Projectile motion (near earth's surface)**

$$\mathbf{r}(t) = x(t)\hat{\mathbf{i}} + y(t)\hat{\mathbf{j}}$$

$$\mathbf{v}(t) = \frac{d\mathbf{r}}{dt} = v_x(t)\hat{\mathbf{i}} + v_y(t)\hat{\mathbf{j}}$$

$$\mathbf{a}(t) = \frac{d\mathbf{v}}{dt} = -g\hat{\mathbf{j}}$$

$$\Rightarrow \mathbf{v}(t) = \mathbf{v}_i - gt\hat{\mathbf{j}} \quad \text{note that } \mathbf{v}(t=0) = \mathbf{v}_i$$

$$\Rightarrow \mathbf{r}(t) = \mathbf{r}_i + \mathbf{v}_i t - \frac{1}{2}gt^2\hat{\mathbf{j}} \quad \text{note that } \mathbf{r}(t=0) = \mathbf{r}_i$$

**Projectile motion (near earth's surface)**

**Trajectory equation in vector form:**

$$\mathbf{r}(t) = \mathbf{r}_i + \mathbf{v}_i t - \tfrac{1}{2} g t^2 \hat{\mathbf{j}} \qquad \mathbf{v}(t) = \mathbf{v}_i - g t \hat{\mathbf{j}}$$

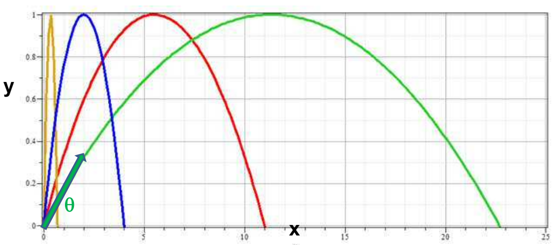
**Trajectory equation in component form:**

$$x(t) = x_i + v_{xi} t \qquad v_x(t) = v_{xi}$$
$$y(t) = y_i + v_{yi} t - \tfrac{1}{2} g t^2 \qquad v_y(t) = v_{yi} - g t$$

**Aside: The equations for position and velocity written in this way are call "parametric" equations. They are related to each other through the time parameter.**



**Diagram of various trajectories reaching the same height h=1 m:**






**Projectile motion (near earth's surface)**

**Trajectory equation in component form:**

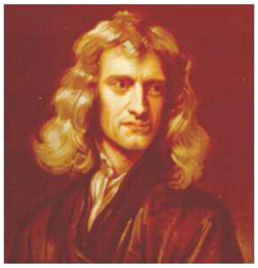
$$x(t) = x_i + v_{xi} t = x_i + v_i \cos\theta_i t$$
$$y(t) = y_i + v_{yi} t - \tfrac{1}{2} g t^2 = y_i + v_i \sin\theta_i t - \tfrac{1}{2} g t^2$$
$$v_x(t) = v_{xi} = v_i \cos\theta_i$$
$$v_y(t) = v_{yi} - g t = v_i \sin\theta_i - g t$$

**Trajectory path *y(x)*; eliminating *t* from the equations:**

$$t = \frac{x - x_i}{v_i \cos\theta_i} \qquad y(x) = y_i + v_i \sin\theta_i \frac{x - x_i}{v_i \cos\theta_i} - \tfrac{1}{2} g \left( \frac{x - x_i}{v_i \cos\theta_i} \right)^2$$

$$y(x) = y_i + \tan\theta_i (x - x_i) - \tfrac{1}{2} g \left( \frac{x - x_i}{v_i \cos\theta_i} \right)^2$$

**Isaac Newton, English physicist and mathematician (1642—1727)**



1. In the absence of a net force, an object remains at constant velocity or at rest.
2. In the presence of a net force F, the motion of an object of mass m is described by the form F=ma.
3. $F_{12} = -F_{21}$.

http://www.newton.ac.uk/newton.html

9/24/2013 PHY 113 C Fall 2013-- Lecture 9 28

**Newton's second law**

F = m a

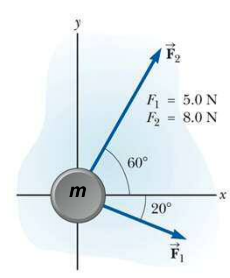
Types of forces:

| Fundamental | Approximate | Empirical |
|---|---|---|
| Gravitational | F=-mg **j** | Friction |
| Electrical | | Support |
| Magnetic | | Elastic |

Elementary particles

9/24/2013 PHY 113 C Fall 2013-- Lecture 9 29

**Example of two dimensional motion on a frictionless horizontal surface**

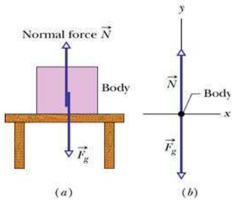



$$\mathbf{F}_1 + \mathbf{F}_2 = m\mathbf{a}$$

$$\mathbf{a} = \frac{\mathbf{F}_1 + \mathbf{F}_2}{m}$$

9/24/2013 PHY 113 C Fall 2013-- Lecture 9 30

Example – support forces

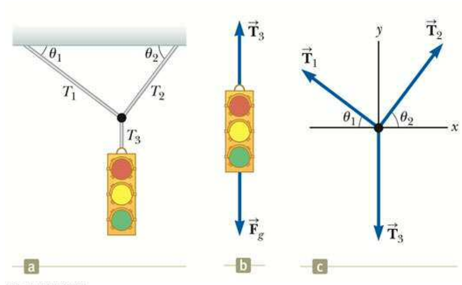



$$\mathbf{F}_g = -mg\hat{\mathbf{y}}$$
$$\mathbf{F}_{\text{support}} = -\mathbf{F}_{\text{applied}}$$

➔$\mathbf{F}_{\text{support}}$ acts in direction $\perp$ to surface
(in direction of surface "normal")

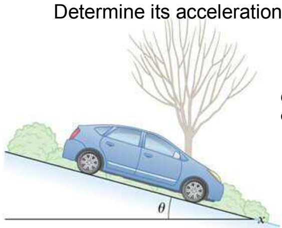


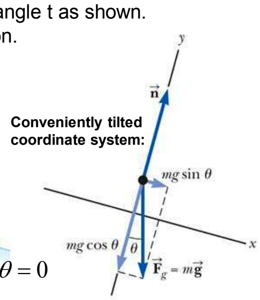
**Example of forces in equilibrium**






**Example: 2-dimensional forces**
A car of mass m is on an icy (frictionless) driveway, inclined at an angle t as shown. Determine its acceleration.



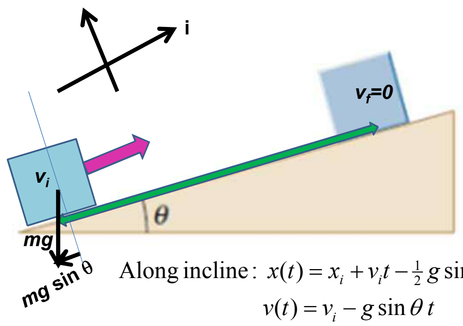




Along $y$: $n - mg\cos\theta = 0$

Along $x$: $mg\sin\theta = ma_x$

$a_x = g\sin\theta$

**Another example:**
**Note: we are using a tilted coordinate frame**




$$\text{Along incline}: \; x(t) = x_i + v_i t - \tfrac{1}{2} g \sin\theta \, t^2$$
$$v(t) = v_i - g \sin\theta \, t$$



## Friction forces

The term "friction" is used to describe the category of forces that *oppose* motion. One example is surface friction which acts on two touching solid objects. Another example is air friction. There are several reasonable models to quantify these phenomena.

Surface friction: $f = \begin{cases} -F_{applied} \\ \pm \mu N \end{cases}$ Normal force between surfaces

Material-dependent coefficient

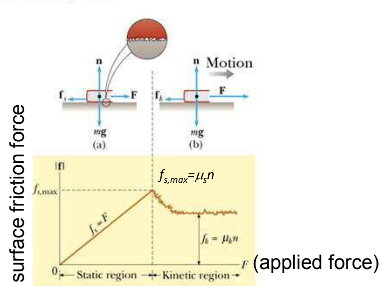
Air friction: $D = \begin{cases} -Kv & \text{at low speed} \\ -K'v^2 & \text{at high speed} \end{cases}$

*K* and *K'* are materials and shape dependent constants



## Models of surface friction forces

Serway, Physics for Scientists and Engineers, 5/e
Figure 5.17

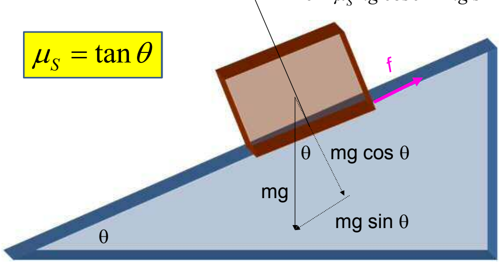



Coefficients $\mu_s$ , $\mu_k$ depend on the surfaces; usually, $\mu_s > \mu_k$

**Consider a stationary block on an incline:**

$$n - mg\cos\theta = 0 \quad \Rightarrow n = mg\cos\theta$$
$$f - mg\sin\theta = 0 \quad \Rightarrow f = mg\sin\theta$$
$$\text{If } \ f = f_{S,\max} = \mu_S n = \mu_S mg\cos\theta$$
$$\text{Then } \ \mu_S mg\cos\theta = mg\sin\theta$$

$$\boxed{\mu_S = \tan\theta}$$

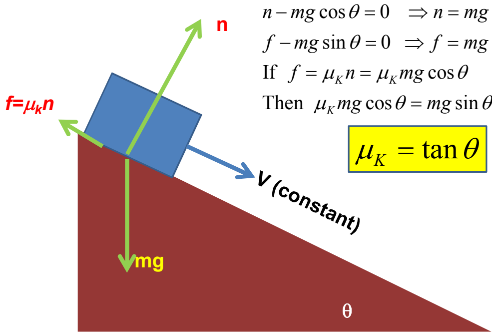





**Consider a block sliding down an inclined surface; constant velocity case**

$$n - mg\cos\theta = 0 \quad \Rightarrow n = mg\cos\theta$$
$$f - mg\sin\theta = 0 \quad \Rightarrow f = mg\sin\theta$$
$$\text{If } \ f = \mu_K n = \mu_K mg\cos\theta$$
$$\text{Then } \ \mu_K mg\cos\theta = mg\sin\theta$$

$$\boxed{\mu_K = \tan\theta}$$

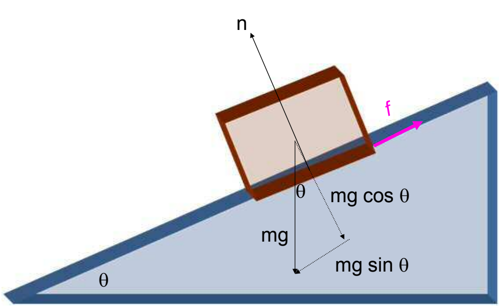




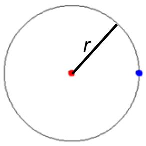

**Summary**

$\mu_K = \tan\theta$ when block moves at constant velocity

$\mu_S = \tan\theta$ when block is just about to slip



### Uniform circular motion and Newton's second law

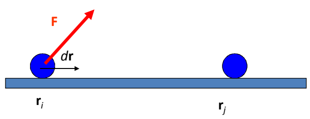



$$\mathbf{F} = m\mathbf{a}$$

$$\mathbf{a}_c = -\frac{v^2}{r}\hat{\mathbf{r}}$$



### Definition of work:




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

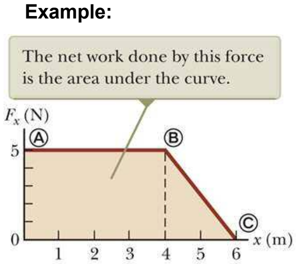
Units of work :

Work = (Newtons)(meters) ≡ (Joules)

1 J = 0.239 cal



### Example:




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

**Work and potential energy**

$$\text{Definition of work}: \quad W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r}$$

Definition of potential energy:

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

**Note: It is assumed that F is conservative**



**Review of energy concepts:**

$$\text{Definition of work}: \quad W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}\cdot d\mathbf{r}$$

$$\text{Definition of kinetic energy}: \quad K = \frac{1}{2}mv^2$$

Work - kinetic energy theorem:

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



**Summary of work, potential energy, kinetic energy relationships**

Work - kinetic energy theorem:

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

$$W_{i\to f}^{total} = W_{i\to f}^{conservative} + W_{i\to f}^{dissipative}$$

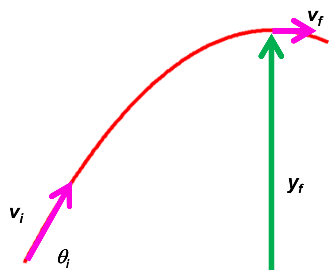
$$= -(U_f - U_i) + W_{i\to f}^{dissipative}$$

$$W_{i\to f}^{total} = -(U(\mathbf{r}_f) - U(\mathbf{r}_i)) + W_{i\to f}^{dissipative} = K_f - K_i$$

$$\text{Rearranging}: \quad K_f + U_f = K_i + U_i + W_{i\to f}^{dissipative}$$

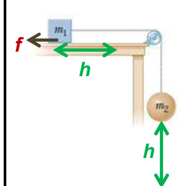
## Example problem from Webassign #8

A baseball outfielder throws a 0.150-kg baseball at a speed of 37.2 m/s and an initial angle of 31.0°. What is the kinetic energy of the baseball at the highest point of its trajectory?






## Example problem from Webassign #8




The coefficient of friction between the block of mass $m_1$ = 3.00 kg and the surface in the figure below is $\mu_k$ = 0.440. The system starts from rest. What is the speed of the ball of mass $m_2$ = 5.00 kg when it has fallen a distance $h$ = 1.85 m?

$$K_f + U_f = K_i + U_i + W_{i\to f}^{dissipative}$$

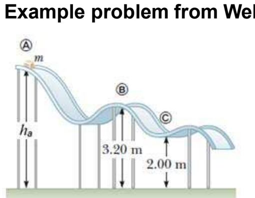
$$W_{i\to f}^{dissipative} = -fh = -\mu_k m_1 g h$$

$$K_f = K_i + (U_i - U_f) + W_{i\to f}^{dissipative}$$

$$\frac{1}{2}(m_1 + m_2)v_f^2 = 0 + m_2 g h - \mu_k m_1 g h$$

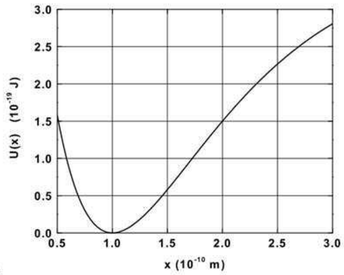


## Example problem from Webassign #8




A block of mass $m$ = 3.40 kg is released from rest from point A and slides on the frictionless track shown in the figure below. (Let $h_a$ = 6.70 m.)

**Example problem from 2012 Exam #2:**




$$W_{i\to f}^{conservative} = -\left(U_f - U_i\right) = -\left(U\left(x_f\right) - U\left(x_i\right)\right)$$

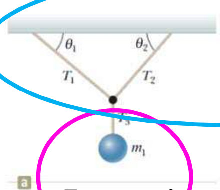
2. The figure above shows a plot of potential energy $U$ (in units of $10^{-19}$ Joules), associated with the conservative forces between two atoms in a molecule, as a function of their separation $x$ in units of $10^{-10}$m. For the purposes of this problem, we will focus on the motion and energy associated with the separation of the atoms, assumed to be confined to the $x$ direction.

(a) What is the work by the interaction forces in the molecule as its separation changes from $x_i = 1 \times 10^{-10}$m to $x_f = 2 \times 10^{-10}$m?

(b) What is the kinetic energy of the molecule when its separation is $x_f = 2 \times 10^{-10}$m, if $K_i = 2 \times 10^{-19}$J at a separation of $x_i = 1 \times 10^{-10}$m?

9/24/2013 PHY 113 C Fall 2013-- Lecture 9 49

**Example problem from Webassign #5**




$$-T_1\cos\theta_1 + T_2\cos\theta_2 = 0$$
$$T_1\sin\theta_1 + T_2\sin\theta_2 - T_3 = 0$$

$$T_3 - m_1 g = 0$$

9/24/2013 PHY 113 C Fall 2013-- Lecture 9 50