

Lecture 1

Physics 106 Spring 2006

<http://web.njit.edu/~sirenko/>

Instructor:

Prof. Andrei Sirenko

<http://web.njit.edu/~sirenko/> and click "Phys 106"
<http://web.njit.edu/~sirenko/PHYSICS-106.htm>

E-mail: sirenko@njit.edu

Office: 423E Tiernan Hall

office hours: Wednesday & Friday
from 11:30 am to 1:00 pm
or by appointment

Course information:

- Physics 106:
Continuation of Classical Mechanics:
- Rotation and Circular motion
- Harmonic Oscillations
- Gravitation

Course Elements:

- › Textbook
- › Lectures (lecture notes)
- › Recitations
- › Homework (due at the beginning of the next Recitation)
- › Exams (3 common exams, final exam)

Textbook:

Halliday, Resnick, and Walker
Fundamentals of Physics, 7th edition
Chapters 10-15th (Volume 1)

(HR&W)

7th edition:



01/18/2006

Andrei Sirenko, NJIT

~~6th edition:~~



5

Web Page:

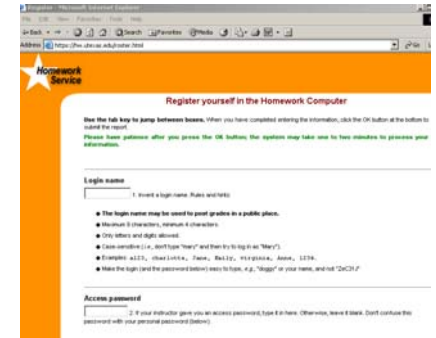
<http://web.njit.edu/~sirenko/>
and click "Phys 106"



01/18/2006

Andrei Sirenko, NJIT

UTexas:
Class: 10615



6

Lectures: (We 1 pm; Tier107)

- > Presentation of the concepts and techniques of Physics.
- > Demonstrations of Physics in action.
- > Lecture quiz at the end of every lecture
- > Lectures are not a substitute for reading the text!
Text chapters are listed on the lecture schedule.
Read ahead; you'll get more from lecture.
- > Slides will be posted on the course web.
Use these as a study guide/note taking aid.

Recitations (Fr. 10 am; Tier 113)

- > Recitations provide an opportunity to do a group activity relevant to the topic being studied, and to ask homework questions.
- > The scenarios presented in the recitation group activities will be on the exams.

01/18/2006

Andrei Sirenko, NJIT

7

Grade Components:

48% for all three common exams (16% each)

32% for the final exam

7% for the total homework grade

5% for the total lecture quiz grade

8% for the workshop grade submitted by your WS instructor

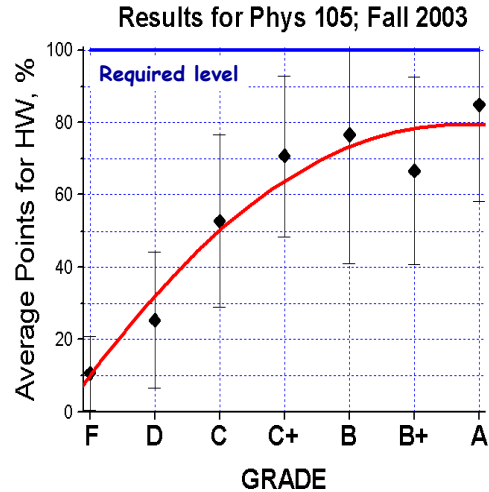
01/18/2006

Andrei Sirenko, NJIT

8

How to Do Well

- Keep up!
- Do the **homework** carefully and understand the reason for each step.
- Form a study group to discuss homework problems.
- Do plenty of extra problems and examples.
- The material gets more difficult through the term. Don't slack off if you are doing well!

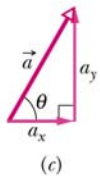
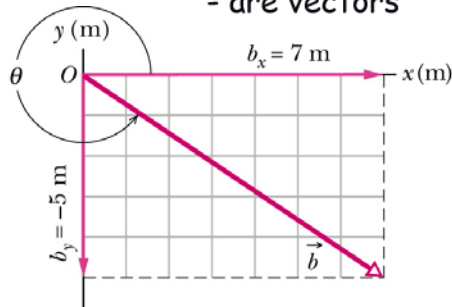
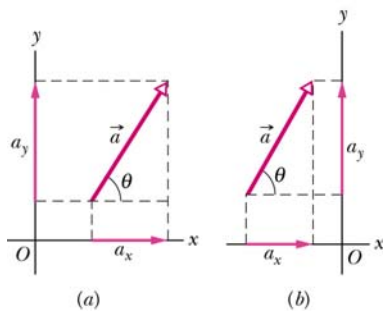


What should we know ?

- › **Vectors**
addition, subtraction, scalar multiplication
- › **Trigonometric functions**
 $\sin \theta, \cos \theta, \tan \theta, \theta = \tan^{-1}(a/b), \text{ etc.}$
- › **Integration and Derivatives (basic concepts)**
 $2x = (x^2)'$
- › **SI Units**
- › **Newton's Laws**
 $F = ma \quad F_{12} = -F_{21}$
- › **Energy Conservation**
Kinetic Energy, Potential Energy, and Work
- › **Circular motion and Centripetal Force**
 $a^c = v^2/R$

Components of Vectors:

- aligned along axis
- add to give vector
- are vectors



$$a_x = a \cos \theta \quad \text{and} \quad a_y = a \sin \theta$$

$$a = \sqrt{a_x^2 + a_y^2} \quad \text{and} \quad \tan \theta = \frac{a_y}{a_x}$$

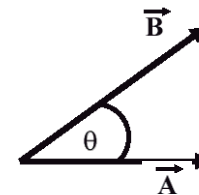
Length (Magnitude)

Vector Multiplication

Dot product

$$\vec{A} \cdot \vec{B} = AB \cos \theta = A_x B_x + A_y B_y + A_z B_z$$

θ is the angle between the vectors if you put their tails together



$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$$

since $\cos(\theta) = \cos(-\theta)$

TABLE 2-1 Equations for Motion with Constant Acceleration^a

Equation Number	Equation	Missing Quantity
2-11	$v = v_0 + at$	$x - x_0$
2-15	$x - x_0 = v_0t + \frac{1}{2}at^2$	v
2-16	$v^2 = v_0^2 + 2a(x - x_0)$	t
2-17	$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
2-18	$x - x_0 = vt - \frac{1}{2}at^2$	v_0

^a Make sure that the **acceleration** is indeed constant before using the equations in this table.

What does zero mean ?

- > $t = 0$ beginning of the process
- > $x = 0$ is arbitrary; can set where you want it
- > $x_0 = x(t=0)$; position at $t=0$; do not mix with the origin

- > $v(t) = 0$ x does not change $x(t) - x_0 = 0$
- > $v_0 = 0$ $v(t) = at$; $x(t) - x_0 = at^2/2$
- > $a = 0$ $v(t) = v_0$; $x(t) - x_0 = v_0 t$

-
- > $a \neq 0$ $v(t) = v_0 + at$; $x(t) - x_0 = v_0 t + at^2/2$
- help: $t = (v - v_0)/a$ $x - x_0 = \frac{1}{2}(v^2 - v_0^2)/a$
 $a = (v - v_0)/t$ $x - x_0 = \frac{1}{2}(v + v_0)t$

- > Acceleration and velocity are positive in the same direction as displacement is positive

Newton's Laws

- If no net **force** acts on a body, then the body's velocity cannot change.
- The net **force** on a body is equal to the product of the body's mass and acceleration.
- When two bodies interact, the **force** on the bodies from each other are always equal in magnitude and opposite in direction ($F_{12} = -F_{21}$)

Force is a vector

Force has direction and magnitude

Mass connects Force and acceleration:

$$\vec{F}_{\text{tot}} = 0 \Leftrightarrow \vec{a} = 0 \text{ (constant velocity)}$$

$$\vec{F}_{\text{tot}} = m\vec{a} \text{ for any object}$$

$$F_{\text{tot},x} = ma_x \quad F_{\text{tot},y} = ma_y \quad F_{\text{tot},z} = ma_z$$

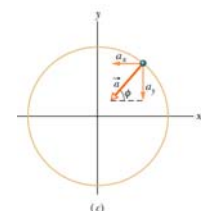
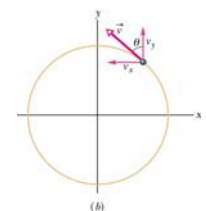
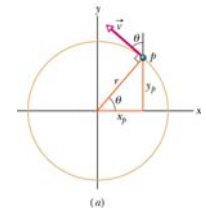
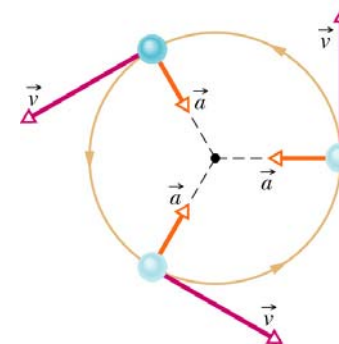
Uniform Circular Motion

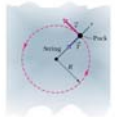
Centripetal acceleration

$$a = \frac{v^2}{r}$$

Period

$$T = \frac{2\pi r}{v}$$





$$ma_c = mv^2/R = \Sigma F$$

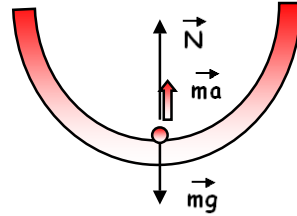
(all forces along the direction towards the center)

> Gravitational Force: \vec{mg}
down to the ground

> Tension Force: \vec{T}
along the string

> Normal Force: \vec{N}
perpendicular to the support

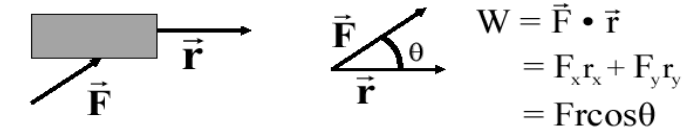
> Static Friction Force
maximum value $F_{fr}^{max} = \mu_{st}N$



$$ma = N - mg$$

$$ma = mv^2/R$$

What does $W = \vec{F} \cdot \vec{r}$ mean?



$W > 0$ if $\theta < 90^\circ$ → force is adding energy to object

$W < 0$ if $\theta > 90^\circ$ → force is reducing energy of object



$W = 0$ if $r = 0$ or $F = 0$ or $\vec{F} \perp \vec{r}$

Work Examples

Push on a wall

$W = 0$ since wall does not move ($\vec{r} = 0$)

Kinetic Energy:

$$K = \frac{1}{2}mv^2$$

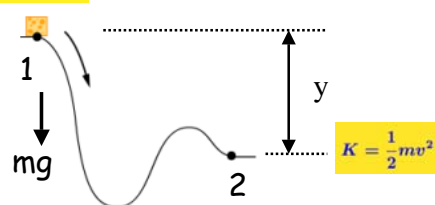
Potential Energy:

$$\Delta U = -W$$

• Gravitation: $U = mgy$

• Elastic (due to spring force): $U = \frac{1}{2}kx^2$

$$U = mgy$$



$U \rightarrow K$

Conservation of Mechanical Energy

$$K_2 + U_2 = K_1 + U_1$$

$$E_{mec} = K + U$$

Kinetic Energy:

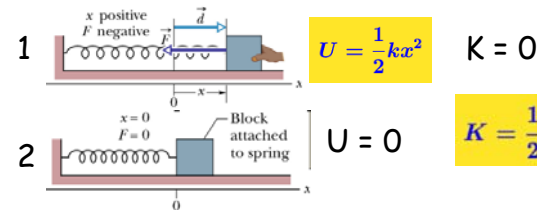
$$K = \frac{1}{2}mv^2$$

Potential Energy:

$$\Delta U = -W$$

• Gravitation: $U = mgy$

• Elastic (due to spring force): $U = \frac{1}{2}kx^2$



$$U = \frac{1}{2}kx^2 \quad K = 0$$

$$U = 0 \quad K = \frac{1}{2}mv^2$$

$U \leftrightarrow K$

Conservation of Mechanical Energy

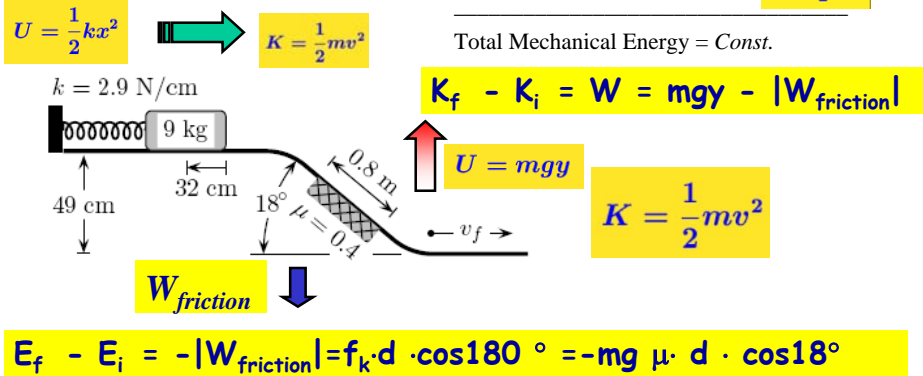
$$K_2 + U_2 = K_1 + U_1$$

$$E_{mec} = K + U$$

Examples for Energy Conservation

- Kinetic Energy changes $K = \frac{1}{2}mv^2$
- + Gravitational Potential Energy $U = mgy$
- + Elastic Potential Energy $U = \frac{1}{2}kx^2$

Total Mechanical Energy = Const.



Linear Momentum

Particle:

$$\vec{p} = m\vec{v}$$

System of Particles:

$$\vec{P} = m_1\vec{v}_1 + m_2\vec{v}_2 + \dots$$

Extended objects:

$$\vec{P} = M\vec{v}_{com}$$

Relation to Force: $\vec{F}_{tot} = m\vec{a}$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}$$

$$\vec{F}_{net} = \frac{d\vec{P}}{dt}$$

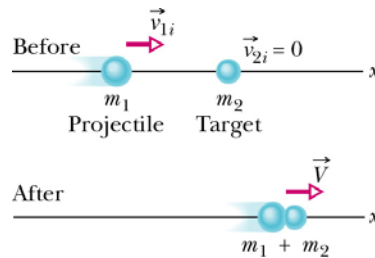
Completely Inelastic Collision Collisions in 1D

Conservation of Linear Momentum works!

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

$$m_1 v_{1i} = (m_1 + m_2) V$$

$$V = \frac{m_1}{m_1 + m_2} v_{1i}$$



Example: Two equal objects, one initially at rest

$$mv_i = 2mv_f \longrightarrow v_f = v_i/2$$

Final Kinetic Energy = $\frac{1}{2}(2m)(v_i/2)^2$ Half the original Kinetic Energy

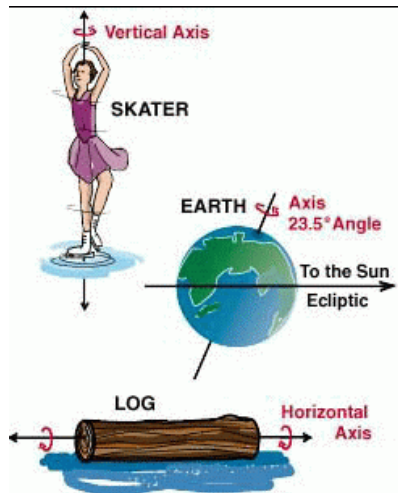
$$= \frac{1}{4}m(v_i)^2$$

Lecture 1

Rotation concepts & variables.
Motion diagrams, FBD's.
Rotation kinematics
Chapter 10 (1-5)

<http://web.njit.edu/~sirenko/>

Rotation; Examples



<http://www.ce.utexas.edu/prof/olivera/Earth.htm>

01/18/2006

Andrei Sirenko, NJIT

25

Rotational Motion



Uniform Circular Motion:
Spinning at steady rate

- > 33 1/3 rpm
- > 45 rpm

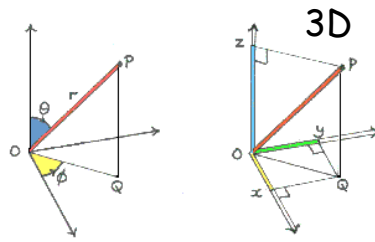
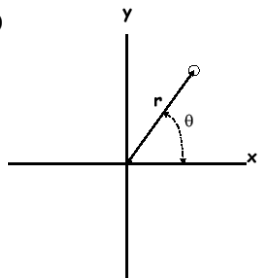
01/18/2006

Andrei Sirenko, NJIT

26

Changing x,y,z coordinates into spherical polar coordinates

2D



$OQ = r \sin \theta$ so $x = r \sin \theta \cos \phi$, $y = r \sin \theta \sin \phi$ and $z = r \cos \theta$

$$r = \sqrt{x^2 + y^2} \iff x = r \cos(\theta)$$

$$\theta = \tan^{-1}(y/x) \iff y = r \sin(\theta)$$

01/18/2006

Andrei Sirenko, NJIT

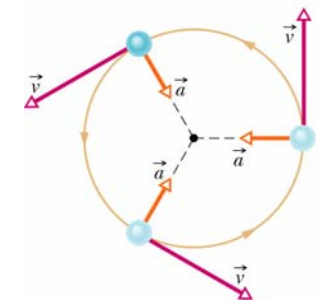
27

Uniform Circular Motion (Phys 105)

Object travels around a circle at constant speed

Centripetal acceleration

$$a = \frac{v^2}{r}$$



Period: $T = 2\pi r/v \equiv$ time to go around once

01/18/2006

Andrei Sirenko, NJIT

28

Uniform Circular Motion in Polar Coordinates

$$\theta(t) = \omega t + \theta_0$$

$$r = r_0$$

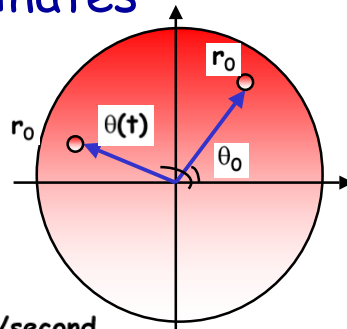
θ angular position radians

ω angular velocity radians/second

$$\omega = v/r \text{ where } v \text{ is the linear speed around the circle}$$

$$\text{Linear velocity along circle: } v = ds/dt = r d\theta/dt$$

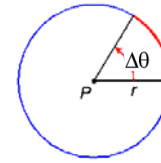
$$v = r\omega$$



01/18/2006

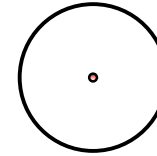
29

Radian



$$1 \text{ Radian} = 180^\circ / \pi \approx 57.3^\circ$$

The arc length is equal to the radius $\Delta s = r\Delta\theta$



$$\text{Circle: } 360^\circ = 2\pi \text{ radians} \approx 6.283 \text{ radians}$$

$$\frac{1}{2} \text{ Circle: } 180^\circ = \pi \text{ radians} \approx 3.1415 \text{ radians}$$

> Radians = degrees $\times (\pi / 180)$

> 1 degree = $\pi / 180 = 0.0174532925$ radians.

> $180^\circ = 3.14156$ radians

> $90^\circ = 1.5708$ radians

> $45^\circ = 0.7854$ radians

01/18/2006

Andrei Sirenko, NJIT

30

Angular Acceleration

$$\alpha = \frac{d\omega}{dt}$$

Plays same role in rotational motion as acceleration in linear motion

$$\alpha = 0 \not\Rightarrow \vec{a} = 0$$

Example: uniform circular motion

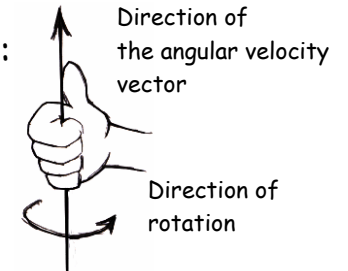
01/18/2006

Andrei Sirenko, NJIT

31

Angular variables are vectors

Direction of the vector:
Right-hand-rule



Sign of $\Delta\theta$:

"Clocks are negative"



Positive $\Delta\theta$ Negative $\Delta\theta$

Sign of $\Delta\theta$ and ω is the same: $\omega = \Delta\theta/\Delta t$
 $\omega = d\theta/dt$

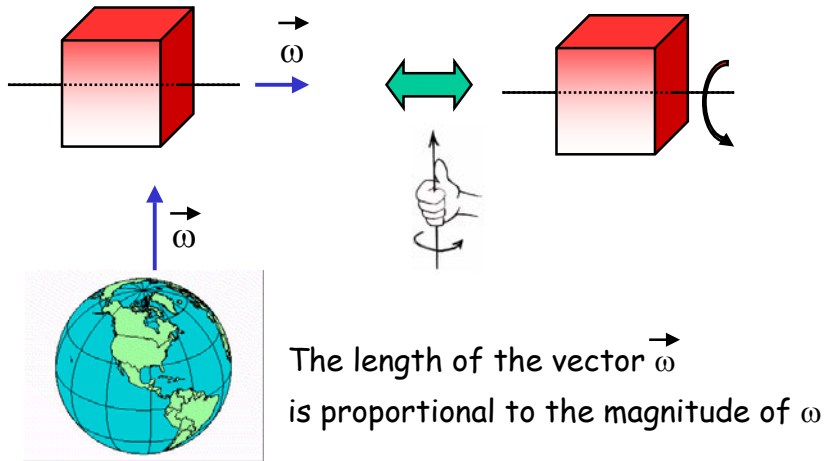
Signs of ω and α can be the same or different

01/18/2006

Andrei Sirenko, NJIT

32

Example:



01/18/2006

Andrei Sirenko, NJIT

33

Rotational Kinematics:

Linear Displacement	\leftrightarrow	Angular Displacement
Linear Velocity	\leftrightarrow	Angular Velocity
Linear Acceleration	\leftrightarrow	Angular Acceleration

$$\vec{x}, \vec{v}, \vec{a} \leftrightarrow \vec{\theta}, \vec{\omega}, \vec{\alpha}$$

If α is constant:

$$\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega = \frac{d\theta}{dt} \rightarrow \omega(t) = \omega_0 + \alpha t$$

$$\text{combine: } 2\alpha(\theta - \theta_0) = \omega^2 - \omega_0^2$$

01/18/2006

Andrei Sirenko, NJIT

34

TABLE 2-1 Equations for Motion with Constant Acceleration^a

Equation Number	Equation	Missing Quantity
2-11	$v = v_0 + at$	$x - x_0$
2-15	$x - x_0 = v_0 t + \frac{1}{2} at^2$	v
2-16	$v^2 = v_0^2 + 2a(x - x_0)$	t
2-17	$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
2-18	$x - x_0 = vt - \frac{1}{2} at^2$	v_0

^a Make sure that the **acceleration** is indeed constant before using the equations in this table.

01/18/2006

Andrei Sirenko, NJIT

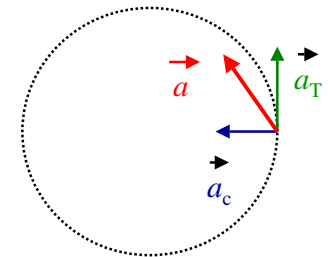
35

Acceleration in Circular Motion:

General Case:

The velocity changes with time.

ω is not constant ($\alpha \neq 0$)



There are two components of **acceleration**: $a_c = v^2 / r = r \omega^2$

> **Centripetal** (radial, towards the center) and

> **Tangential** (along the velocity vector)

$$a_T = r \alpha$$

> **Total acceleration** value:

$$\vec{a} = \vec{a}_c + \vec{a}_T; \quad a = (a_c^2 + a_T^2)^{1/2}, \quad \tan \phi = a_T / a_c$$

01/18/2006

Andrei Sirenko, NJIT

36

Homework

See the **Physics 106 Course Syllabus**

FOP Chapter 10:

U of Texas: Register for the Class 10615

And start working on the first HW!

<http://web.njit.edu/~sirenko/>