Instructor:

Prof. Andrei Sirenko

E-mail: sirenko@njit.edu
Office: 423E Tiernan Hall
• Office hours: Wednesday 2:30 – 4:00 pm
• Friday 11:30 – 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)
➢ Workshop
➢ Lab (separate grade)
Textbook:

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

(Lecture 1 Andrei Sirenko, NJIT 6)

Web Page:

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

and click "Phys 106 Spring 2007"

(UTexas: Class: 11787)

Lectures: (Wednesdays 1:00 pm; TH107)

- 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 (10:00 am; TH107)

- 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.

Grade Components:

- 48% for all three common exams (16% each)
- 32% for the final exam
- 8% for the total homework grade
- 4% for the total lecture quiz grade
- 8% for the workshop grade submitted by your WS instructor

"Phys 106 Workshop assignments will be posted at the course WebCT site at http://webct.njit.edu; enter your UCID and password to have an access to this site. Please contact the Help Desk at 973-596-2900 for questions regarding your UCID and password."

"Students are required to bring their own printed copies to the WS and Recitation class."

(Andrei Sirenko, NJIT 7)
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
  - $\sin \theta$, $\cos \theta$, $\tan \theta = \tan^{-1}(a/b)$, etc.
- Integration and Derivatives (basic concepts)
  - $2x = (x^2)'$
- SI Units
- Newton's Laws
  - $F = ma$
- 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

Vector Multiplication

Dot product

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

$\theta$ 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

<table>
<thead>
<tr>
<th>Equation Number</th>
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<td>2-11</td>
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*Make sure that the acceleration is indeed constant before using the equations in this table.*

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### Newton’s Laws

I. If no net force acts on a body, then the body’s velocity cannot change.

II. The net force on a body is equal to the product of the body’s mass and acceleration.

III. When two bodies interact, the force on the bodies from each other are always equal in magnitude and opposite in direction (\( F_{12} = -F_{21} \)).

**Centripetal acceleration**

\[ a = \frac{v^2}{r} \]

**Period**

\[ T = \frac{2\pi r}{v} \]
Gravitational Force: \( mg \) down to the ground

Tension Force: \( T \) along the string

Normal Force: \( N \) perpendicular to the support

Static Friction Force: maximum value \( F_{\text{fr max}} = \mu_s N \)

\[ ma_c = \frac{mv^2}{R} = \Sigma F \]

(all forces along the direction towards the center)

\[ ma = N - mg \]
\[ ma = \frac{mv^2}{R} \]

Kinetic Energy:
\[ K = \frac{1}{2} mv^2 \]

Potential Energy:
\[ \Delta U = -W \]

- Gravitation: \[ U = mgy \]
- Elastic (due to spring force): \[ U = \frac{1}{2} kx^2 \]

Conservation of Mechanical Energy
\[ K_2 + U_2 = K_1 + U_1 \]

Work Examples

Push on a wall
\[ W = 0 \] since wall does not move (\( \vec{r} = 0 \))
Examples for Energy Conservation

- Kinetic Energy changes
- Gravitational Potential Energy
- Elastic Potential Energy

Total Mechanical Energy = Const.

\[ K_f - K_i = W = mg \Delta y - |W_{friction}| \]

\[ U = mgy \]

\[ K = \frac{1}{2}mv^2 \]

Linear Momentum

Particle:
\[ \vec{p} = m\vec{v} \]

System of Particles:
\[ \vec{P} = m_1\vec{v}_1 + m_2\vec{v}_2 + \ldots \]

Extended objects:
\[ \vec{P} = \sum m_i\vec{v}_{i,com} \]

Relation to Force:
\[ \vec{F}_{tot} = ma \]

Completely Inelastic Collision
Collisions in 1D

Conservation of Linear Momentum works!
\[ \vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f} \]

\[ m_1v_{1i} = (m_1 + m_2)V \]

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

Example: Two equal objects, one initially at rest
\[ mv_i = 2mv_f \quad \Rightarrow \quad v_f = v_i/2 \]

Final Kinetic Energy = \[ \frac{1}{2}(2m)(v/2)^2 = \frac{1}{4}m(v_i)^2 \] Half the original Kinetic Energy
Rotation; Examples

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

Rotational Motion

Uniform Circular Motion:
Spinning at steady rate

33 1/3 rpm
45 rpm

Uniform Circular Motion
(Phys 105)

Object travels around a circle at constant speed

Centripetal acceleration

\[ a = \frac{v^2}{r} \]

Period: \[ T = \frac{2\pi r}{v} \equiv \text{time to go around once} \]
Uniform Circular Motion in Polar Coordinates

\[ \theta(t) = \omega t + \theta_0 \]
\[ r = r_0 \]

\( \theta \) angular position \hspace{1cm} \text{radians}

\( \omega \) angular velocity \hspace{1cm} \text{radians/second}

\( \omega = \frac{v}{r} \) where \( v \) is the linear speed around the circle

Linear velocity along circle: \( v = \frac{ds}{dt} = r\frac{d\theta}{dt} \)

\[ v = r\omega \]

Radian

1 Radian = \( 180^\circ \) / \( \pi \) \( \approx 57.3^\circ \)

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

Circle: \( 360^\circ = 2\pi \) radians \( \approx 6.283 \) radians

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

- Radians = degrees \times (\pi / 180)
- 1 degree = \( \pi / 180 \approx 0.0174532925 \) radians.
- \( 180^\circ = 3.14156 \) radians
- \( 90^\circ = 1.5708 \) radians
- \( 45^\circ = 0.7854 \) radians

Angular Acceleration

\[ \alpha = \frac{d\omega}{dt} \]

Plays same role in rotational motion as acceleration in linear motion

\[ \alpha = 0 \Leftrightarrow \vec{a} = 0 \]

Example: uniform circular motion

Angular variables are vectors

Direction of the vector: Right-hand-rule

Sign of \( \Delta\theta \):

- "Clocks are negative"
- Positive \( \Delta\theta \) \hspace{1cm} Negative \( \Delta\theta \)

Signs of \( \omega \) and \( \alpha \) can be the same of different
Example:

The length of the vector $\omega$ is proportional to the magnitude of $\omega$.

Rotational Kinematics:

- Linear Displacement $\leftrightarrow$ Angular Displacement
- Linear Velocity $\leftrightarrow$ Angular Velocity
- Linear Acceleration $\leftrightarrow$ Angular Acceleration

If $\alpha$ is constant:

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

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

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

Rotation:

Angular Displacement
Angular Velocity
Angular Acceleration

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Homework

See the Physics 106 Course Syllabus

FOP Chapter 10:

U of Texas: Register for the Class 11787
And start working on the first HW!
Bring the printouts to the Recitation class

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

QZ: Our linear velocity with respect to the Sun

\[ \text{R}_{E-S} = 1.5 \times 10^{11} \text{ m} \quad \text{T}=1 \text{ year} = 365 \text{ days} \]

\[ \text{v} = \omega R = \frac{2\pi R}{T} \]

\[ \omega = \frac{2\pi}{T} \]

When do we move faster?
(a) Day
(b) Night

What is the velocity difference between Day and Night at the Equator line?

\[ |(V_{\text{day}} - V_{\text{night}})|/V_{\text{average}} \]

(a) 0.00008
(b) 0.015
(c) 0.03
(d) 0.3
(e) 100%

Show work!

Acceleration in Circular Motion:

General Case:
The velocity changes with time.

\( \omega \) is not constant (\( \alpha \neq 0 \))

There are two components of acceleration:

\[ a_c = \frac{v^2}{r} = r \omega^2 \]

- Centripetal (radial, towards the center) and
- Tangential (along the velocity vector)

\[ a_T = r \alpha \]

Total acceleration value:

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