Wed. 9/8 Thurs 9/9 Fri. 9/10	**1.1-.3** Intro to Mechanics & to Computation in Mechanics **1.4,.6** Mass, Force, Newton's 1st & 2nd.	
Mon. 9/13 Wed. 9/15 Thurs 9/16 Fri. 9/17	**1.5,.7** Newton's 3rd & Polar Coordinates **2.1-.2** Air Resistance - Linear **2.3** Trajectory and Range with Linear Resistance	**HW1**

Handouts:

- Syllabus
- My schedule for office hours
- Project handout
- HW Section 1
- Euler-Cromer Method – <u>bring the Python files</u>!
- VPython double pendulum & 3-body orbits
- White boards

- **Big Picture: Fundamental Principle of Mechanics**
    - As I just told the Phys 231 students this morning, almost all of our time in this class will be spent on just one idea: *Motion is neither created nor destroyed, but transferred via interactions.*
    - We'll spend most of our time quantifying that sentiment in different ways, and modeling its application to different systems to see its consequences.
- **Why Classical Mechanics *Again?***
    - You've already studied Classical Mechanics in General Physics, but there are a variety of reasons for studying it further (some of them related):
        - Get more practice, especially at more difficult and realistic problems
            - For example add air resistance.
                - 05_bassball.py (231 – without, 331 *with* air resistance)
        - Learn more advanced concepts and methods
            - Lagrange's approach
                - Crazy systems like a string through a hole in a table connecting one ball orbiting on the table's surface and one hanging below – really easy using his approach.
            - Calculus of variations
                - Finding the equation the describes the shape of a string hanging in a uniform gravitational field – really easy by this approach.
        - It's interesting and there are still surprises
            - Pendulum

- Single pendulum in 231 – could write the equations and predict the future
- Double Pendulum - can write the equations of motion, but it is unpredictable after a short time (an example of chaos)
  - 03_double_pendulum.py
  - Interestingly, the mirrors used in LIGO's interferometers (intended to detect gravitational waves) are mounted as triple pendulums to reduce the transmission of vibrations from the earth, through the vacuum chamber to the mirrors.

Rough Outline of Topics for the Semester:

1. Newton's Laws (Ch. 1) – also brief review of kinematics
2. Projectiles with air resistance (Ch. 2) – application of Newton's Second Law
3. Momentum and angular momentum (Ch. 3)
4. Energy (Ch. 4)
5. Oscillations (Ch. 5) MOSTLY REVIEW but deeper

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6. Calculus of Variations (Ch. 6) MOSTLY NEW
7. Lagrange's Equations (Ch. 7)
8. Two-body, central-force problems (Ch. 8)
9. Rotational motion of rigid bodies (Ch. 10)
10. Noninertial reference frames (Ch. 9)

Go over the syllabus:

- Office Hours – mark a "b" on the times that are *bad.* For office hours for you.
- Do the reading assignments before class.
- **Discussion Prep.**
  - By 9am on class days, turn in 3 things to help you prepare for class – these can be questions from the reading, filling in the blanks from something in the reading, working an unassigned problem, a first go at one of the homework problems associated with the day's reading.
- **HW:**
  - Usually due Thursdays by 4pm. No late HW. There will be a lot, so start it early!
  - Units must be included in calculations (not just tacked on at the end). Also, vector notation (e.g. $\vec{A}$, not A) must be used for all vectors quantities!
  - Work together, but do not copy or allow your work to be copied!

Projects –go over the separate handout

Office hours – pass around my schedule and ask them to mark *bad* times for office hours.

Let's get started.

This will all be review. Don't worry, we'll get into new stuff (or at least new depths with old stuff) soon enough.

<u>Vector Notation</u>:

We will need a way to distinguish scalars and vectors, which have both size and direction. One of the vectors that we will use very frequently is the position vector. This and other vectors are typeset in bold in the textbook (i.e. $\mathbf{r}$) That is not convenient for handwriting, so I will insist upon "arrow notation" (i.e. $\vec{r}$).

Once you have chosen a coordinate system, there are many ways to describe the position of a point *P* relative to the origin. Often, we give the components (x, y, and z) along the axes of the coordinate system. We can also label the components with subscripts (e.g. r_x is the x component of $\vec{r}$), which is more convenient for other vectors. We will use two ways to write vectors (<u>not</u> numbered components, r_1 & $\hat{e}_1$):

- using unit vectors: $\vec{r} = x\hat{x} + y\hat{y} + z\hat{z} = r_x\hat{x} + r_y\hat{y} + r_z\hat{z}$
- abbreviated notation: $\vec{r} = (x, y, z) = (r_x, r_y, r_z)$

For other vectors, label the components with subscripts (e.g. a_x is the x component of $\vec{a}$).

<u>Vector Operations</u>: Suppose we have another vector $\vec{s} = (s_x, s_y, s_z)$ in addition to $\vec{r}$.

On a white board write these out in terms of components:

1. **sum**: $\vec{r} + \vec{s} = (r_x + s_x, r_y + s_y, r_z + s_z)$
2. **multiplication by a scalar**: $c\vec{r} = (cr_x, cr_y, cr_z)$
3. **scalar (or dot) product** (the result is a scalar): $\vec{r} \cdot \vec{s} = r_x s_x + r_y s_y + r_z s_z = rs\cos\theta$, where r and s are the magnitudes of the vectors and θ is the angle between them.
4. **magnitude of a vector**: $r = |\vec{r}| = \sqrt{r_x^2 + r_y^2 + r_z^2} = \sqrt{\vec{r} \cdot \vec{r}}$, sometimes $\vec{r} \cdot \vec{r}$ is abbreviated as $\vec{r}^{\,2}$, but it is a scalar!
5. **vector (or cross) product** (the result is a vector):

$$\vec{r} \times \vec{s} = \det\begin{bmatrix} \hat{x} & \hat{y} & \hat{z} \\ r_x & r_y & r_z \\ s_x & s_y & s_z \end{bmatrix} = (r_y s_z - r_z s_y)\hat{x} + (r_z s_x - r_x s_z)\hat{y} + (r_x s_y - r_y s_x)\hat{z}$$

→ 11_crossproduct.py

Now, this one we won't use for a while, so if you don't immediately know what use it will be, don't sweat it.

<u>Derviatives of Vectors</u>:

Taking a time derivative of a vector using the product rule:

$$\frac{d\vec{r}}{dt} = \frac{d}{dt}\left(r_x\hat{x} + r_y\hat{y} + r_z\hat{z}\right) = \left(\frac{dr_x}{dt}\right)\hat{x} + r_x\left(\frac{d\hat{x}}{dt}\right) + \left(\frac{dr_y}{dt}\right)\hat{y} + r_y\left(\frac{d\hat{y}}{dt}\right) + \left(\frac{dr_z}{dt}\right)\hat{z} + r_z\left(\frac{d\hat{z}}{dt}\right),$$

but the Cartesian unit vectors do not change (unit vectors do for other coordinates), so:

$$\frac{d\vec{r}}{dt} = \left(\frac{dr_x}{dt}\right)\hat{x} + \left(\frac{dr_y}{dt}\right)\hat{y} + \left(\frac{dr_z}{dt}\right)\hat{z}$$

The sum of two vectors:

$$\frac{d}{dt}\left(\vec{r} + \vec{s}\right) = \frac{d\vec{r}}{dt} + \frac{d\vec{s}}{dt}$$

Product of scalar and vector:

$$\frac{d}{dt}\left(f\vec{r}\right) = f\frac{d\vec{r}}{dt} + \frac{df}{dt}\vec{r}$$

<u>Euler-Cromer Method</u> – You will encounter many differential equations that cannot be solved analytically (or just easily). Go over the handout and the VPython code. Emphasize that there will be computational HW problems on most assignments.

Hand out

→ Show examples

Email code

Next two classes:

- Friday – Newton's Laws in Cartesian coordinates
- Monday – Polar coordinates & momentum conservation