Internet of Things (IoT) at UCF

UNIVERSITY OF CENTRAL FLORIDA

UCF RET Site: Collaborative Multidisciplinary Engineering Design Experiences for Teachers

2003430: AP Physics C (Mechanics)

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RET Site: CoMET Lesson/Unit Plan

Course(s): AP Physics C Mechanics
Grade Level: 9-12
Suggested Length of Lesson: Approximately 5 class periods (50 minute class)

Materials/Technology Needed

- Accelerometers (Vernier low-g, smart phone with app to measure acceleration using phone sensor; PocketLab sensor)
- Computer(s) for data analysis and presentation
- Fan Cart (for "constant" acceleration) or modified Atwood's system with horizontal track
- LoggerPro software for Vernier data collection
- Smart Phone with PhyPhox (or other app)
- Smart Phone with video recording capability (slow motion if possible)
- Tracker software (free, open-source video analysis software)
- Python (Python3)

Where this Fits

- Kinematics (with calculus)
  (My students have all had at least one year of physics without calculus prior to this, so the basic kinematic concepts will be review. The inclusion of the calculus to determine derivatives and integrals of the kinematic data is "new," although most of the students have had calculus previously.

Lesson Objective(s)/Learning Goal(s)

- Students will be able to
- describe physical principles behind measuring acceleration
- describe basics of smart phone accelerometers
- apply calculus relationships among acceleration, velocity and displacement
- apply and compare numerical and analytical integration techniques

Standard(s)/Benchmark(s) Addressed

AP PHYSICS C: MECHANICS

A. Kinematics (including vectors, vector algebra, components of vectors, coordinate systems, displacement, velocity and acceleration)

1. Motion in one dimension

a) Students should understand the general relationships among position, velocity and acceleration for the motion of a particle along a straight line, so that:

1) Given a graph of one of the kinematic quantities, position, velocity or acceleration, as a function of time, they can recognize in what time intervals the other two are positive, negative, or zero and can identify or sketch a graph of each as a function of time.

2) Given an expression for one of the kinematic quantities, position, velocity or acceleration, as a function of time, they can determine the other two as a function of time, and find when these quantities are zero or achieve their maximum and minimum values.

b) Students should understand the special case of motion with constant acceleration, so they can:

1) Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities.

2) Use the equations $v_x = v_{x0} + a_x t$, $x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2$, and $v_x^2 = {v_{x0}}^2 + 2a_x (x - x_0)$ to solve problems involving one-dimensional motion with constant acceleration.

c) Students should know how to deal with situations in which acceleration is a specified function of velocity and time so they can write an appropriate differential equation and solve it for $v(t)$ by separation of variables, incorporating correctly a given initial value of v.

Standards for Mathematical Practice

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Instructional Strategies

- Modeling
- Multiple Representations
- Scaffolding
- Compare/Contrast; Summarizing
- Cooperative Learning
- Reflection (Students write reflections)

Evidence of Learning (Assessment Plan)

- Pre/Post of Measuring Kinematic Variable Questions Responses
- Lab Summary (Report and Whiteboard Presentation)
- Python programming summary/analysis

Description of Lesson Activity/Experiences

1. *Class Discussion about how we measure kinematic variables:*
   (a) elicit student ideas by having students work in small groups to brainstorm and share on whiteboards, first by asking for ideas without looking things up on their cell phones and then by having them use their phone or a class laptop to research
   (b) assign one topic for each group to investigate more thoroughly for class presentation if groups find a good variety; else have pre-prepared accelerometer mechanisms ready to seed/assign (see Measuring Acceleration Teacher Notes)
   (c) relate acceleration, velocity, and displacement via calculus relationships (see handout)

2. Measuring Kinematic Data Activity – Students will design and conduct an investigation using various means to determine displacement and acceleration of an object. They will compare displacements and accelerations from data acquired through (1) video analysis, (2) motion detector, (3) photogates, and (4) Vernier's low-g accelerometer, PocketLab or smartphone accelerometer measurements. Students will analyze data and turn in an informal group report. On the day the report is due, students will participate in whiteboard presentation activity.

3. Introduction to Numerical Integration – Using the Python (free, open source) programming language, students will learn basic numerical integration techniques and examine/compare errors in results. Sample programs will be modeled and discussed and students will have a few short exercises to complete and answer analysis questions regarding. (Ideally, the end goal is to use numerical integration techniques to integrate data produced by the accelerometer part of the experiment, but this may be too difficult to implement without spending more time than available. Students' previous programming experience will determine if we attempt to do this.)

Recommended Assessment(s) and Steps

- Informal formative assessment with class discussion and whiteboard presentations
- Informal formative assessment during class practice of analytic derivative and integration rules
- Informal lab "report" (Data and Analysis only)
- Summary of Python program results/answers to analysis questions

List of Materials/Resources Used

- See list of materials/technology

Important Vocabulary

Term	Definition
Acceleration	Acceleration is the rate of change of velocity.
Accelerometer	Accelerometers are devices that measure acceleration.
Displacement	Displacement is the change in position of an object.
MEMS	MEMS stands for micro-electromechanical systems. MEMS devices are found in many modern technologies, including MEMS accelerometers.
Velocity	Velocity is the rate of change of position.

Troubleshooting Tips

Ensure that students have access to all needed software prior to implementation.

Other Helpful Information

My students have all had at least a year of previous physics and understand kinematic relationships for constant acceleration. For students who have never had physics, more background information about the relationships among displacement, velocity and acceleration would be needed.

Suggested Background Information for Teachers:
https://sites.math.washington.edu/~wcasper/math307_win16/review/euler_method/euler_method.pdf

https://countsp.trinket.io/ap-physics-with-python#/welcome/introduction

Attachments

- Measuring Kinematic Data Lab Activity Instructions
- Teacher Notes for Kinematic Data Lab Activity
- Numerical Differentiation and Integration “Handout”
- Teacher Notes for Numerical Differentiation and Integration Activity
- Python Programs for N

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